ADDITIONAL HYDROGEOLOGICAL & SOILS ANALYSIS

of the

Unified Disposal District Landfill

Havre, Montana

OCTOBER, 1993

Prepared by:

Damschen & Associates, Inc.
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ADDITIONAL HYDROGEOLOGICAL AND SOILS ANALYSIS FOR THE UNIFIED DISPOSAL DISTRICT LANDFILL HAVRE, MONTANA

October, 1993

Prepared by:

DAMSCHEN & ASSOCIATES, INC.
Helena, Montana

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INTRODUCTION

This report is being written in response to developmental activity centered around the Unified Disposal District landfill east of Havre, Montana. Included within this report are a brief review of the previous investigations performed at the landfill, a summary of remedial actions, the planning and fate of an expansion area, and the development and implementation of a ground water monitoring network.

Purpose and Scope

This report is intended to fully develop the hydrogeologic and soils characterization at the Unified Disposal District landfill east of Havre, Montana. It is also intended to serve as a basis for the development of a Ground Water Monitoring Network and related Sampling and Analysis Plan for detection monitoring at the landfill as outlined in the Work Plan submitted to the Montana Solid and Hazardous Waste Bureau (MSHWB). This document also augments the April 21, 1992 review by Damschen & Associates, Inc. of the meeting held on March 16, 1992. This meeting was convened to discuss the review of the Hydrogeologic Analysis for the Existing Sanitary Landfill, which was submitted to the MSHWB in October, 1991.

Organization of Report

Because of the length of the investigatory and remedial history of this site, a section of this document is dedicated to a brief, but hopefully thorough review of activity and reporting at the site to date. While this is intended to be a reasonably complete summary and review of the development of the Unified Disposal District landfill, much of the previously-acquired data are not reproduced herein. The original landfill license application, the interim hydrogeological study, and all relevant correspondence should be available to the reader in order to facilitate a clear understanding of the various situations at the site. Some of these documents and letters are included in various appendices, where appropriate.

Damschen & Associates, Inc. submitted a report entitled "Hydrogeologic and Soils Analysis for the Existing Sanitary Landfill" in October of 1991. This document contains records of all drilling and excavations at the site prior to the date of submittal. It is strongly suggested that the reviewer have this document on hand while appraising the data in this report. Plate 1 of this report shows the locations of all sub-surface investigation points to date, including test pits, test borings, piezometers and ground-water monitoring wells.

Since the discoveries made during the most recent investigations and ground water monitoring event have a significant impact on the characterization of the hydrogeological environment at the landfill, some of the questions raised by the MSHWB in regard to the initial investigation are no longer germane. However, the MSHWB review of the

INTRODUCTION

This report is being written in response to developmental activity initiated among the Unified Disposal District landfill east of Havre, Montana. Included within this report are a brief review of the previous investigations performed at the landfill, a summary of remedial actions, the planning and size of an expansion area, and the development and implementation of a ground water monitoring network.

Purpose and Scope

This report is intended to fully develop the hydrogeologic and soils characterization at the Unified Disposal District landfill east of Havre, Montana. It is also intended to serve as a basis for the development of a Ground Water Monitoring Network and related Sampling and Analysis Plan for detection monitoring at the landfill as outlined in the Work Plan submitted to the Montana Solid and Hazardous Waste Bureau (MSHWB). This document also augments the April 21, 1992 review by Dameron & Associates, Inc. of the meeting held on March 16, 1992. This meeting was convened to discuss the review of the Hydrogeologic Analysis for the Existing Sanitary Landfill, which was submitted to the MSHWB in October, 1991.

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Since the discoveries made during the most recent investigations and ground water monitoring events have a significant impact on the characterization of the hydrogeological environment at the landfill, some of the questions raised by the MSHWB in regard to the initial investigations are no longer pertinent. However, the MSHWB review of the

hydrogeological investigation and the initial response to this review are included within this document in Appendix A.

A portion of this investigation was intended to further explore the possibility of using property adjacent to the landfill as an expansion area. The results and conclusions of this study are included herein.

Another section of this document is a report of the remedial efforts involved with a seepage problem that occurred in 1989. The complete construction details have been submitted to the MSHWB under separate cover. Plate 2 of this document is a site map that includes all of the engineering changes planned or implemented to date.

The remainder of this document is dedicated to reporting, analyzing and evaluating the site hydrogeology and water quality issues. This section deals exclusively with the most recent investigations and does not include some basic information, such as site location, basic geology, and so on. This information is included in the previous report by Damschen & Associates, Inc. (1991).

PREVIOUS INVESTIGATIONS

Landfill Licensing

The initial landfill license includes documentation of a soil investigation, test borings, and well installations at the site. The soil investigation was performed by a representative of the Havre Testing Labs, Inc., of Havre, Montana. A copy of that report can be found in Appendix D of the Damschen & Associates, Inc. 1991 report entitled "Hydrogeologic Analysis for the Existing Sanitary Landfill" prepared for the Unified Disposal District. The investigation by Havre Testing Labs, Inc. included five test excavations to depths of about eight feet. It was concluded in that study that ground water would not be intercepted even at the lowest elevation of refuse disposal.

Subsequent to the surface study, two holes were drilled to water and cased. One of these, denoted as the "shop well" was, as its name implies, used as a water supply for the landfill shop facilities. This well is located near the entrance to the landfill (Plate 1). The other, known as the "observation well", is located several hundred feet to the south of the shop well in the valley bottom (Plate 1). Logs of both of these wells, along with hydrochemical data from the shop well and general discussions of the stratigraphy traversed by each can be found in a earlier report (Damschen & Associates, 1991). The shop well intercepted aquifers with a production capacity of about two gallons per minute at a depth of 76 feet below ground level (BGL). The static water level in this well was last reported at about 49 feet BGL. The water in this well has never been used for human consumption, due to its very poor quality (Damschen & Associates, Inc., 1991).

The observation well intercepted at least two sandy zones, one of which was reported as "moist" at a depth of 30 feet BGL. It is not clear from the well log if this zone is the source of the water that came into the well. It is also not clear what production value, if any, this aquifer holds. The well construction makes the determination of this nearly impossible, because the well casing is open at the bottom and traverses two permeable and, possibly, saturated zones. Some basic water quality data from this well are included in the 1991 Damschen & Associates, Inc. report.

It is important to bear in mind when reviewing hydrochemical data from these two holes that they are cased with steel. In the case of the observation well, the casing is galvanized steel. The presence of such well casing in contact with very saline ground water, such as that found at this site, may significantly influence analytical results. It is anticipated that the observation well will be plugged in the near future due to its questionable value as a data collection point and its proximity to the location of the retention pond that is to be constructed.

PREVIOUS INVESTIGATIONS

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The initial landfill license includes documentation of a soil investigation, test borings, and well installation at the site. The soil investigation was performed by a representative of the Haver Testing Labs, Inc., of Haver, Montana. A copy of the report can be found in Appendix D of the Damascus & Associates, Inc. 1991 report entitled "Hydrogeologic Analysis for the Existing Sanitary Landfill" prepared for the Finded Disposal District. The investigation by Haver Testing Labs, Inc. included five test excavations to depths of about eight feet. It was concluded in that study that ground water would not be intercepted even at the lowest elevation of refuse disposal.

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The observation well intercepted at least two sandy zones, one of which was reported as "moist" at a depth of 50 feet BGL. It is not clear from the well log if this zone is the source of the water that came into the well. It is also not clear what production value, if any, this aquifer holds. The well construction makes the determination of this nearly impossible, because the well casing is open at the bottom and traverses two permeable and, possibly saturated zones. Some basic water quality data from the well are included in the 1991 Damascus & Associates, Inc. report.

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1991 Hydrogeological Report

As previously noted, Damschen & Associates, Inc. performed a hydrogeological and soils investigation during 1989 and 1990, which culminated in a report submitted to the Solid and Hazardous Waste Bureau (MSHWB) in October, 1991. The study involved an investigation of deep ground water for the purpose of ground water monitoring, and an inquiry into the source of a seep on the south side of the fill area.

Initial Ground Water Monitoring Network. A number of test borings were drilled over the entire site in an attempt to find a saturated zone that would meet the definition of an aquifer then in usage. That definition of one gallon per minute was not met by most of the saturated zones encountered during the investigation. The uppermost saturated zone meeting that criterion was finally encountered at depths in excess of 200 feet BGL. Two monitoring wells were cased and are known as MW-1 and MW-2 (Plate 1). The stratigraphy, general hydraulic conditions and hydrochemistry are discussed in the Damschen & Associates, Inc. (1991) report.

Shallow Ground Water Investigation. The unexpected appearance in 1988 of a seep along the southern side of the fill area prompted a study of the shallow ground water in that area. The study was intended to characterize the hydrogeology south of the landfill and propose a remedy to the situation. This study is included in the 1991 report by Damschen & Associates, Inc. Briefly, the study revealed the presence of a mantle of sandy and gravelly glacial deposits atop relatively impermeable Cretaceous-aged clay. The glacial deposits served to store and intermittently transport ground water. Several alternatives were suggested in the Damschen & Associates, Inc. (1991) report. The ultimate solution involved the construction of a ditch that would intercept the ground water and divert it to a detention pond. This remedial effort is discussed in a subsequent portion of this report.

REMEDIATION OF INFILTRATION

As noted previously, seepage from sandy sediments on the southern border of the fill area posed an operational hazard at the landfill on an intermittent basis. During particularly wet years, springs would develop on the southern side of the fill area causing moisture to infiltrate into the waste. The response to this problem was to excavate a trench to a depth sufficient to intercept the moisture and carry it down-gradient of the landfill.

Initially, the diversion ditch was designed to flow from west to east. Prior to construction, however, two problems were encountered: 1) the ditch would have to cross a high pressure gas line and 2) the runoff would have to flow onto private property. Because of these situations, the District officials and the engineer decided to redesign the ditch to flow from east to west. The ditch was completed in June, 1992 and has shown to be effective in intercepting the shallow ground water on the south side of the landfill. This runoff ultimately drains into a small ravine that leads to a detention pond that will be located near the bottom of the large draw within which the landfill is located. The District is intending to bid out the construction of the detention pond and a new access road to the active landfill area in the near future. The location of the diversion ditch, detention pond and new access road are depicted on Plate 2.

As a result of the construction of the drainage trench, the shallow ground water contours depicted in Plate 2 of the 1991 Damschen & Associates, Inc. report can be re-drawn. These contours are depicted in Figure 1 of this report. Figure 1 will also serve as a response to items 4 and 6 of the MSHWB review of March 3, 1992. The ground water is now intercepted by the trench and no longer flows into the fill area.

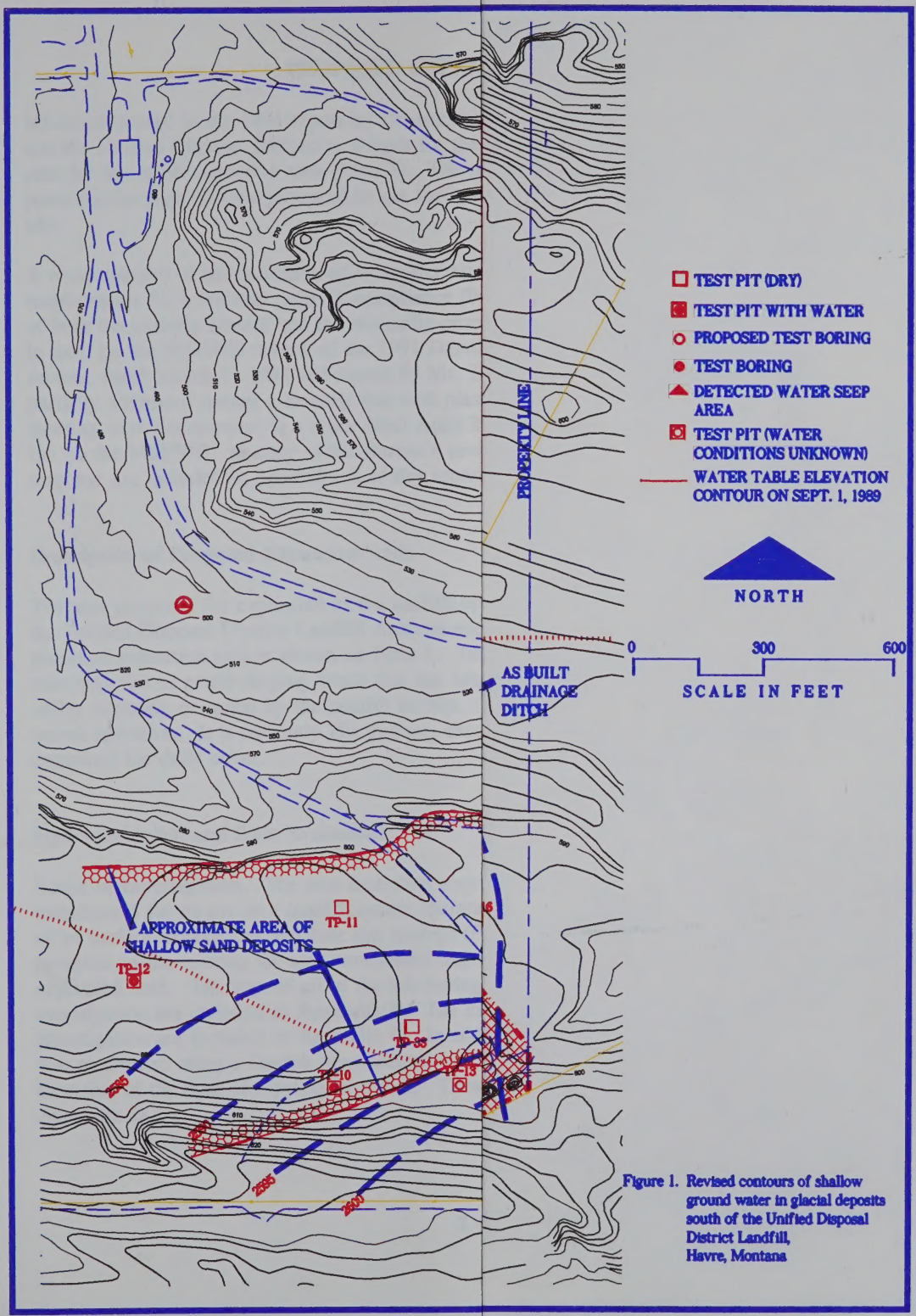
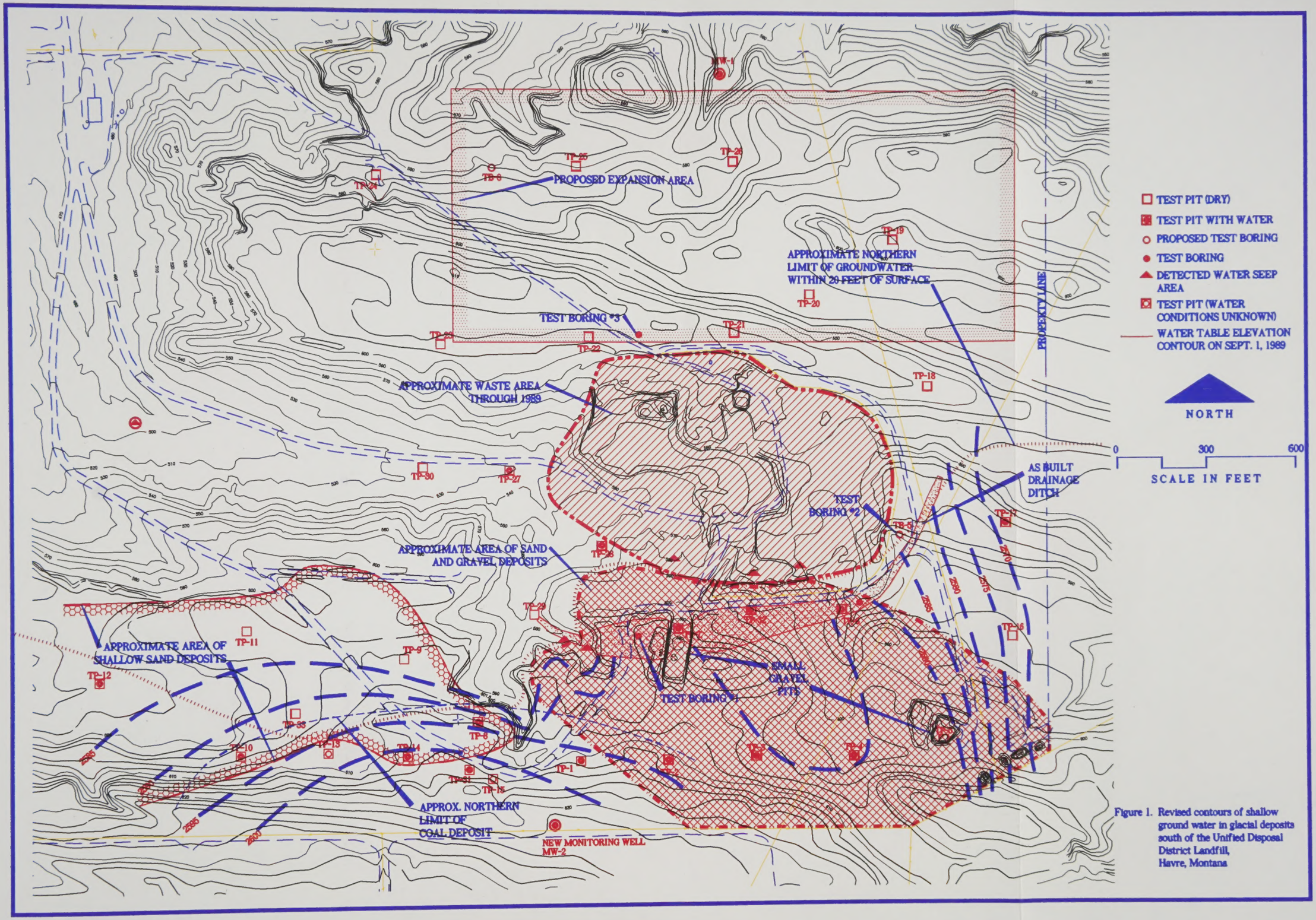


Figure 1. Revised contours of shallow ground water in glacial deposits south of the Unified Disposal District Landfill, Havre, Montana



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PROPOSED EXPANSION AREA

Information used in the 1991 report by Damschen & Associates, Inc. was used by the Firm and the Unified Disposal District as a basis for the evaluation of property adjacent to the fill area for use as an expansion area (Plate 1). The monitoring well MW-1 was sited at that particular location in anticipation of its use for monitoring an area north of the existing fill area.

A re-assessment of the definition of an aquifer along with changes in the location requirements for a relevant point of compliance (POC) prompted a subsequent investigation of both the existing landfill and the originally-proposed expansion area. This was addressed, in part, by the MSHWB review of the 1991 Damschen & Associates, Inc. report. This review, dated March 3, 1992 and signed by Mr. Edward A. Thamke, was discussed and partially addressed during a meeting that took place on March 16, 1992. The results of that meeting were documented in a letter dated April 21, 1992 from Damschen & Associates, Inc. to the MSHWB. A copy of the Bureau's review and the Damschen & Associates, Inc. response are included in Appendix A of this report.

Description of Proposed Expansion Area

The area proposed for expansion of the landfill operation was initially outlined on Sheet 3 of the Unified Disposal District Landfill Analysis and Design folio. A general depiction of the proposed expansion area is shown on Plate 1. The bulk of the area comprises the top of a relatively flat or gently-sloping bench that lies between the Milk River valley and the small valley currently occupied by the landfill facility. The expansion area was designed to be trench operation. It is currently idle pasture, except for a portion to the west that has been excavated for daily cover.

Hydrogeological and Soils Evaluation

Scope of Investigation. The area described above and outlined on Plate 1 was further investigated for its use as a landfill trench operation. The most recent investigation consisted of 14 surface excavations and four test borings (Plate 1). In addition, several test borings proximal to the existing fill area contributed important data to the evaluation of the proposed expansion area. The logs of all of the test borings completed during the most recent investigation are included in Appendix B. The logs of the test pits completed during this investigation are included in Appendix C. In addition, one constant-head permeameter test was performed using a Guelph permeameter in a large surface excavation at the approximate elevation of the base of a proposed trench. These test data and results are included with Appendix D.

PROPOSED EXPANSION AREA

Information used in the 1991 report by Dames & Associates, Inc. was used by the Flats and the Unified Disposal District as a basis for the evaluation of property adjacent to the fill area for use as an expansion area (Plate 1). The monitoring well MW-1 was sited at that particular location in anticipation of its use for monitoring an area north of the existing fill area.

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Results and Discussion. The test pits revealed the presence of the ubiquitous glacial mantle averaging 20 feet in thickness beneath the proposed expansion area (Appendix C). Most of the pits revealed the presence of poorly-sorted interbedded silts and sands, with a few beds of clean sand. Most of the material observed in the pits appeared to be of glaciofluvial or glaciolacustrine origin. This characterization is supported by the test borings on the north side of the existing landfill (Appendix B; Plate 1). Some of the material directly above the fine-grained sediments of the Cretaceous-aged Judith River formation appeared to be ground moraine composed of poorly-sorted clay- to pebble-sized clasts. These sediments, in general, are somewhat finer grained and more poorly sorted than those of similar age south of the fill area that host an intermittent perched aquifer.

A constant-head permeameter was performed at the base of an excavation in the general location of Trench II-1 (Appendix D; Sheet 3 of 19, 1991 Analysis and Design plan set). As previously noted, this location was used for the excavation of daily cover material. The results indicated that the glacial sediments in the portion of the pit tested possess a field-saturated hydraulic conductivity of 5.75×10^{-3} centimeters per second (cm/sec). = 16.3 ft/da.

Shallow ground water was discovered at a depth of about 35 feet in the north-central portion of the proposed expansion area in sediments belonging to the Judith River formation. The test boring in which it was discovered (UDD-16/P-3, Plate 1) was outfitted with a small-diameter well (piezometer). The full lateral extent of this water-bearing zone was not explored, however it is thought to be fairly localized and recharged by local infiltration. The saturated zone here is on the order of a few feet thick and appears to be perched within thin sand beds intercalated within a 15-foot-thick clay stratum. While an aquifer test has not been performed within this zone, the transmissivity of the stratum may be characterized as very low, if the rate at which water entered the piezometer is any indication.

Deeper ground water was encountered in the test borings on the southern extreme of the expansion area as well as to the northeast (Plate 1; Appendix B; Damschen & Associates, Inc., 1991). MW-1 encountered an aquifer of a few gallons per minute at a depth of well over 200 feet, but traversed numerous saturated zones at higher levels (Damschen & Associates, Inc., 1991). A test boring in the northeastern corner of the property (UDD-15 on Plate 1; Figure 2; Appendix B) encountered two saturated zones that produced measurable quantities of water (P-1, P-2 on Plate 1; Figure 2; Appendix B). The saturated zones lie between about 60 and 75 feet BGL and are both hosted by silty sand strata. The relationship between these aquifers and those to the south (Figures 2, 3 and 4), if any, is not clear. Further exploration will be required to establish any hydraulic associations, because correlations over distances of several hundred feet are tenuous, at best.

Conclusions. The original concept for operation of the expansion area was to excavate trenches and employ the material in place for a liner and daily cover. The investigation into the type and quantity of material in this area has given cause for reconsidering of this

Results and Discussion. The test pit revealed the presence of the subjacent glacial marls averaging 20 feet in thickness beneath the proposed expansion area (Appendix C). Also, the test pits revealed the presence of poorly-sorted stratified silt and sand, with a few beds of clean sand. Most of the material observed in the pits appeared to be of glacial-lacustrine or glacial-marine origin. This characterization is supported by the test borings on the north side of the existing basin (Appendix B; Plate 1). Some of the material directly above the fine-grained sediments of the Cretaceous-aged Judith River formation appeared to be ground moraine composed of poorly sorted clay to pebble-sized clasts. These sediments, in general, are somewhat finer grained and more poorly sorted than those of similar age south of the Missouri River that have an unmodified ground moraine appearance.

A constant-head permeameter test was performed at the base of an excavation in the proposed location of Trench II-1 (Appendix D; Sheet 3 of 19, 1991 Analysis and Design plan set). As previously noted, this location was used for the excavation of daily cover material. The results indicated that the glacial sediments in the portion of the pit tested possess a fairly saturated hydraulic conductivity of 5.75 x 10^{-5} centimeters per second (cm/sec).

Shallow ground water was discovered at a depth of about 35 feet in the north-central portion of the proposed expansion area in sediments belonging to the Judith River formation. The test boring in which it was discovered (JDD-16/P-3, Plate 1) was completed with a small-diameter well (piezometer). The full lateral extent of this water-bearing zone was not explored, however it is thought to be fairly localized and recharged by local infiltration. The saturated zone here is on the order of a few feet thick and appears to be perched within thin sand beds intercalated within a 15-foot-thick clay stratum. While an aquifer test has not been performed within this zone, the transmissivity of the stratum may be characterized as very low, if the rate at which water entered the piezometer is any indication.

Deeper ground water was encountered in the test borings on the northern margins of the expansion area as well as to the northeast (Plate 1, Appendix B; Dimension & Associates, Inc., 1991). MW-1 encountered an aquifer of a few gallons per minute at a depth of well over 200 feet, but traversed numerous saturated zones at higher levels (Dimension & Associates, Inc., 1991). A test boring in the northwestern corner of the property (JDD-15 on Plate 1; Figure 2; Appendix B) encountered two saturated zones that produced measurable quantities of water (P-1, P-3 on Plate 1; Figure 2; Appendix B). The saturated zones lie between about 60 and 75 feet BGL and are both based in clay zones. The relationship between these aquifers and those to the south (Figures 2, 3 and 4; Appendix A) are unclear. Further explorations will be required to establish any hydraulic connections, because variations over distances of several hundred feet are unknown, at best.

Conclusions. The original concept for expansion of the existing area was to excavate, transfer and employ the material in place for a liner and daily cover. The investigation into the type and quantity of material in this area has given cause for reconsidering of this

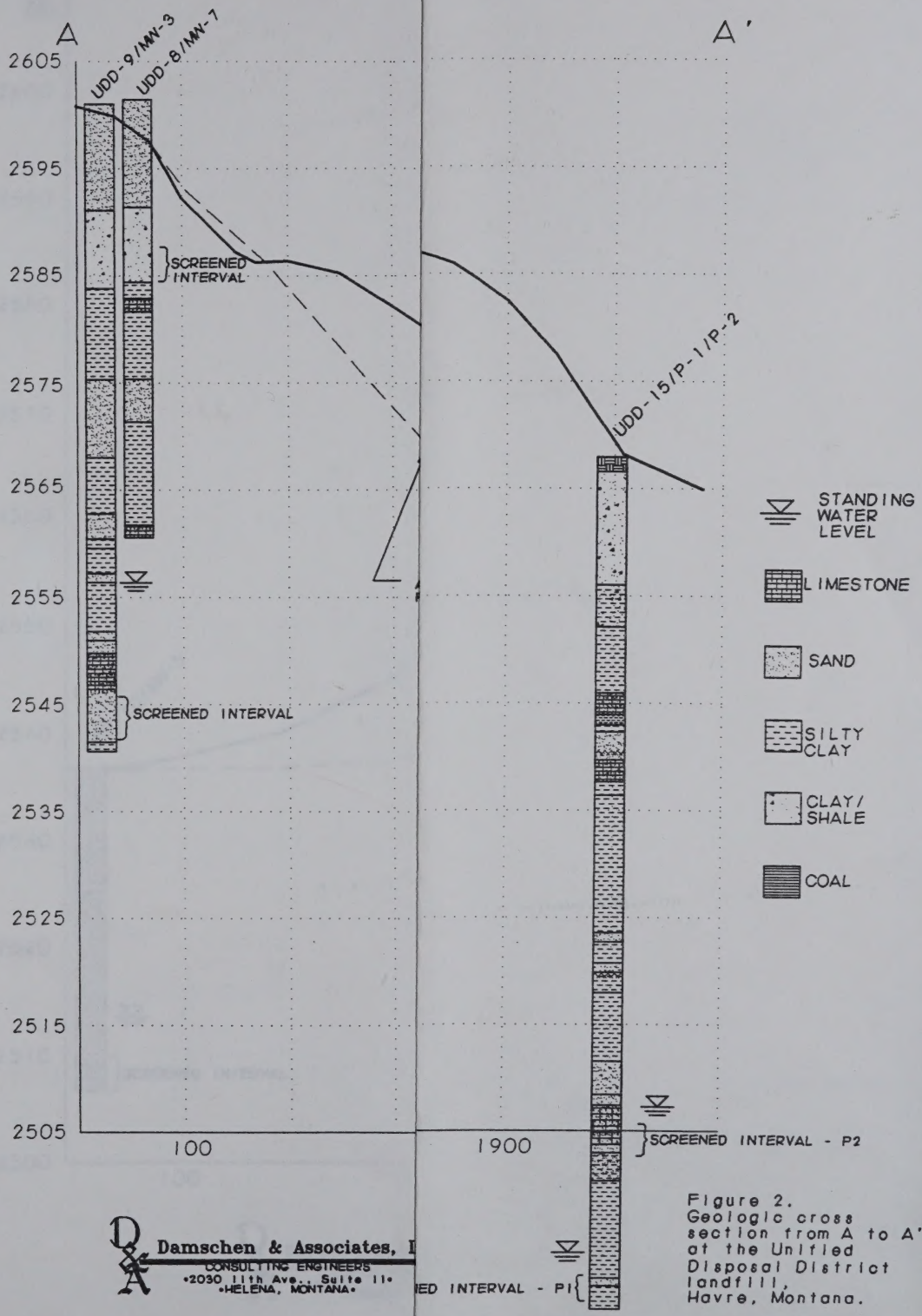

Figure 2.
Geologic cross section from A to A' at the United District landfill, Havre, Montana.

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Results and Discussion. The test pit revealed the presence of the subsurface glacial matrix averaging 20 feet in thickness beneath the proposed expansion area (Appendix C). Most of the pits revealed the presence of poorly-sorted interbedded silts and sands, with a few beds of clean sand. Most of the material observed in the pits appeared to be of glaciofluvial or glaciolacustrine origin. This characterization is supported by the test borings on the west side of the existing landfill (Appendix B, Plate 1). Some of the material directly above the fine-grained sediments of the Cretaceous-aged Judith River formation appeared to be gravel moraine composed of poorly-sorted clay- to pebble-sized clasts. These sediments, in places, are somewhat finer grained and more poorly sorted than those of similar age south of the fill area that rest on an intermittent pedestal aquifer.

A constant-head permeameter was performed at the base of an excavation in the proposed location of Trench II-1 (Appendix D, Sheet 3 of 19; 1991 Analysis and Design plan set). As previously noted, this location was used for the excavation of daily cover material. The results indicated that the glacial sediments in the portion of the pit tested possess a field-saturated hydraulic conductivity of 5.75 x 10^{-5} centimeters per second (cm/sec).

Shallow ground water was discovered at a depth of about 35 feet in the north-central portion of the proposed expansion area in sediments belonging to the Judith River formation. The test boring in which it was discovered (UDD-10/P-3, Plate 1) was outfitted with a small-diameter well (piezometer). The full lateral extent of this water-bearing zone was not explored, however it is thought to be fairly localized and restricted by local inflexion. The saturated zone here is on the order of a few feet thick and appears to be perched within thin sand beds intercalated within a 15-foot-thick clay stratum. While an aquifer test has not been performed within this zone, the transmissivity of the stratum may be characterized as very low, if the rate at which water entered the piezometer is any indication.

Deeper ground water was encountered in the test borings on the western margin of the expansion area as well as in the northeast (Plate 1, Appendix B, Dominion & Associates, Inc., 1991). MW-1 encountered an aquifer of a few gallons per minute at a depth of just over 300 feet, but intersected numerous saturated zones at higher levels (Dominion & Associates, Inc., 1991). A test boring in the northeastern corner of the property (UDD-13 on Plate 1; Figure 2, Appendix B) encountered two saturated zones that produced measurable quantities of water (P-1, P-2 on Plate 1; Figure 2, Appendix B). The saturated zones lie between about 60 and 75 feet BGS, and are both bounded by silty sand strata. The relationship between these aquifers and those to the south (Figures 2, 3 and 4/1/1 Appendix B) is not clear. Further explorations will be required to establish any lateral continuity, because correlations over distances of several hundred feet are tenuous, at best.

Conclusions. The original intended for operation of the expansion area was to excavate trenches and supply the material to place fire a layer and daily cover. The intermittent in both the type and quantity of material in this area has given cause for reconsidering of this

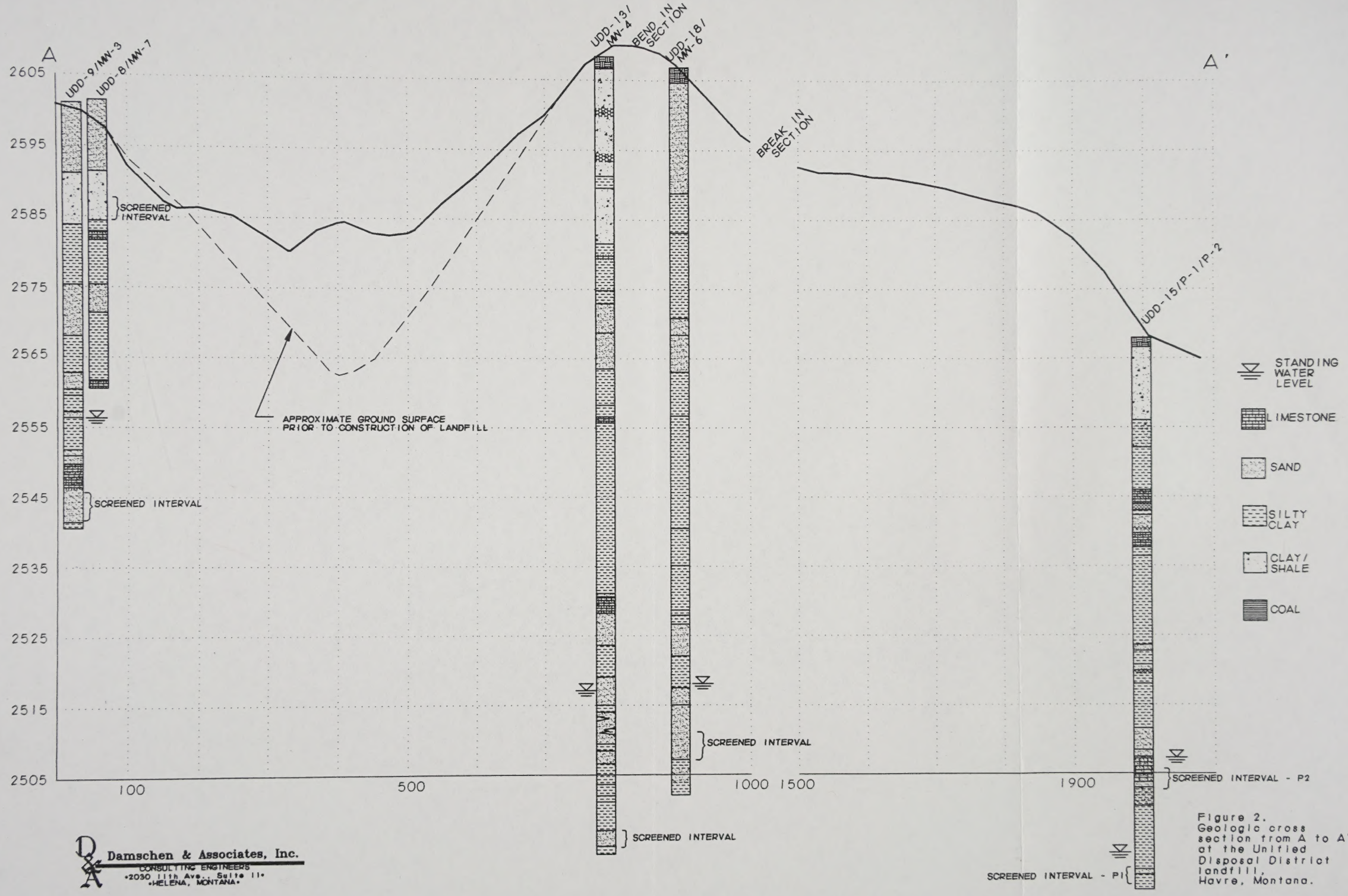

Figure 2.
Geologic cross section from A to A' at the Unified Disposal District landfill, Havre, Montana.

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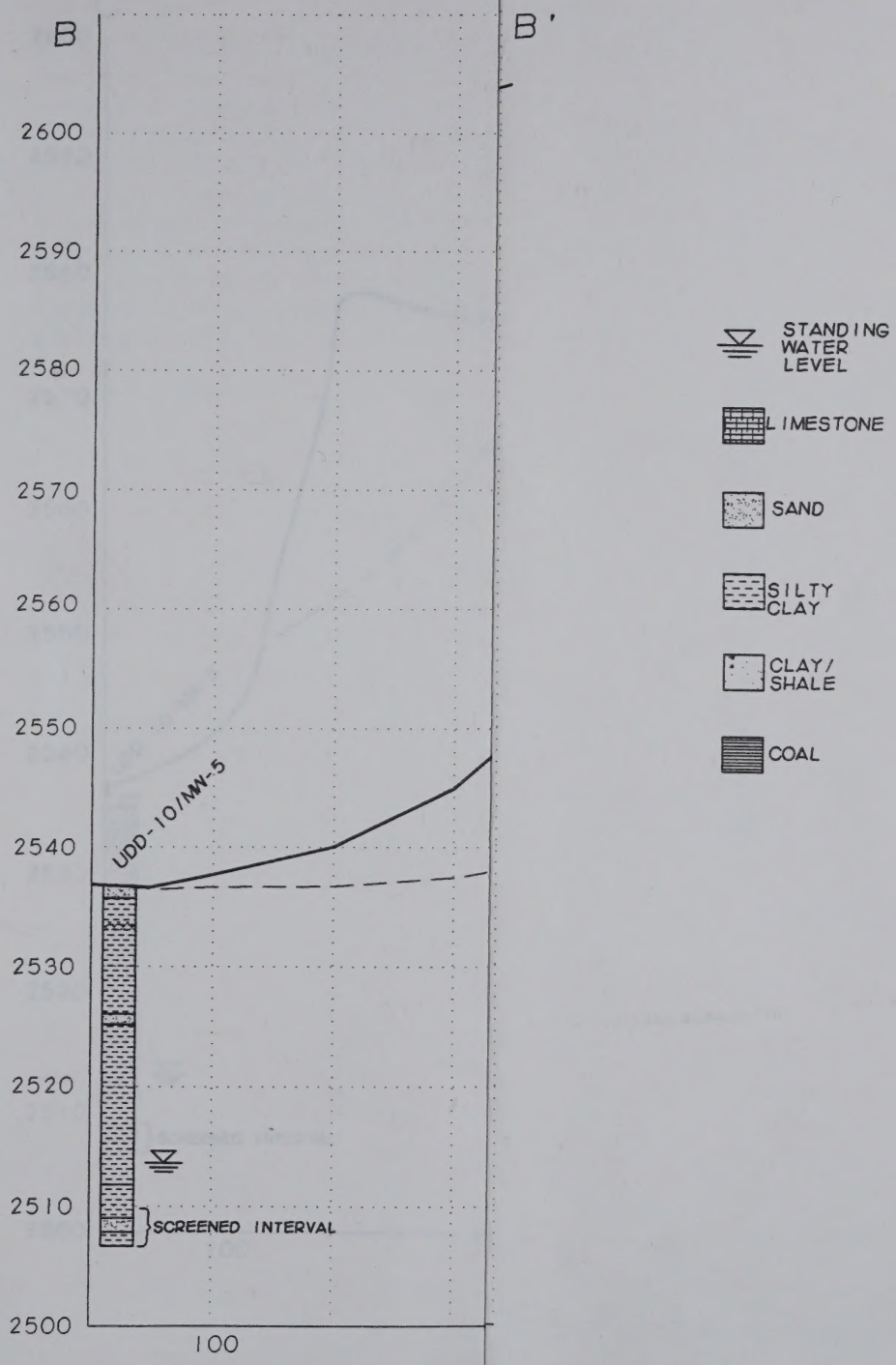

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ross section from B to B' at
posal District landfill, Havre, Montana.

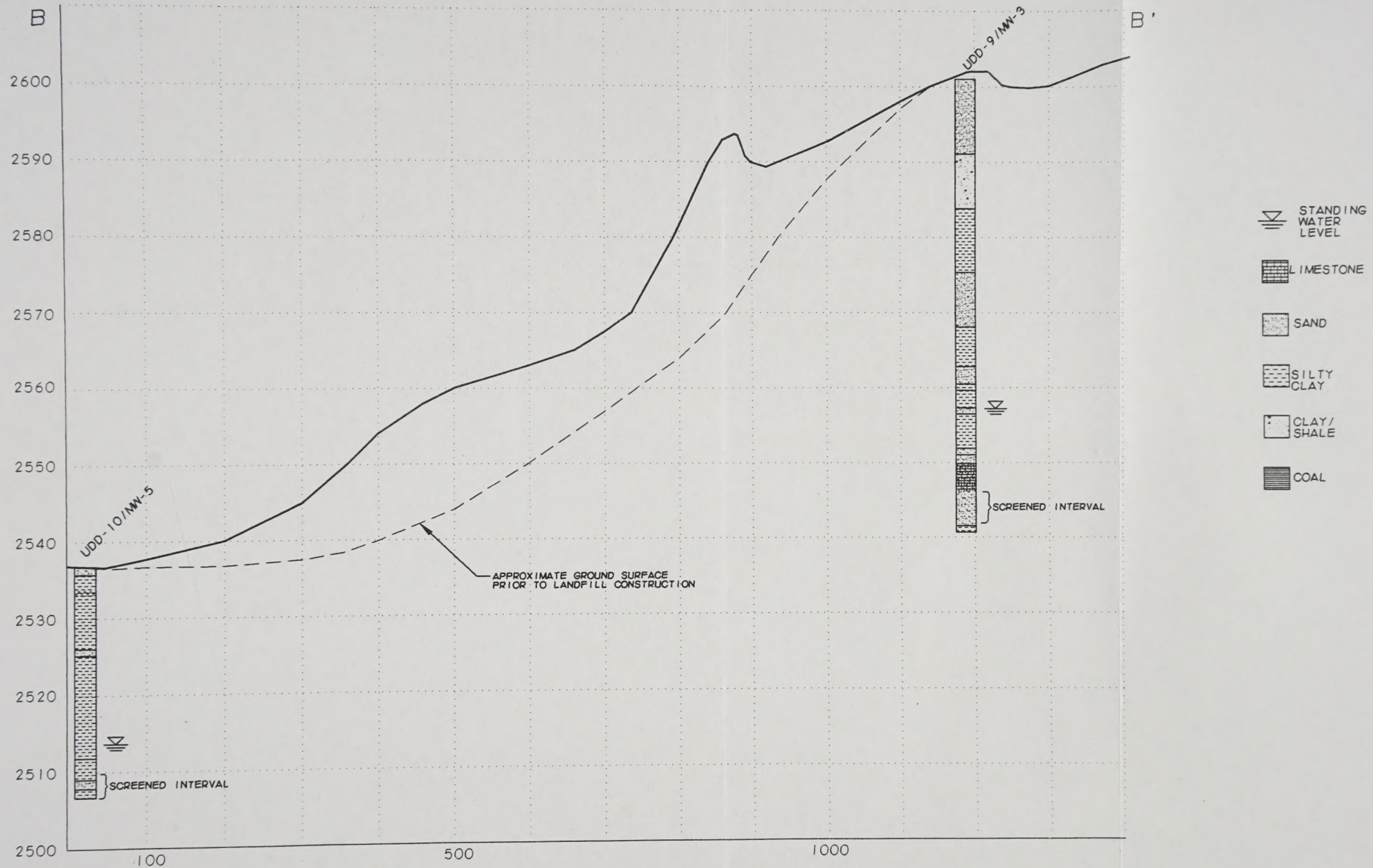

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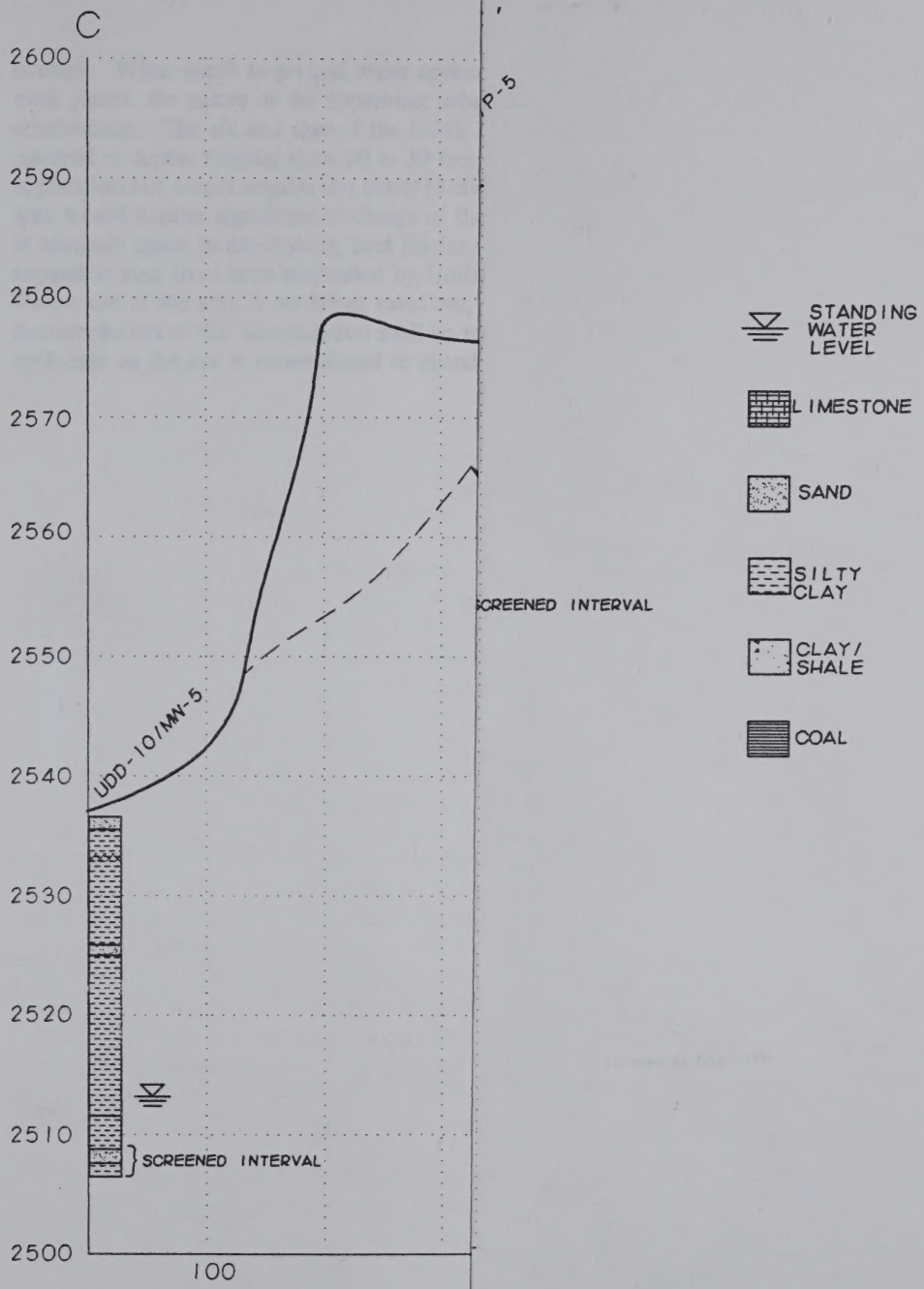
Figure 3. Geologic cross section from B to B' at Unified Disposal District landfill, Havre, Montana.



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Cross section from C to C' at Disposal District landfill, Havre, Montana.

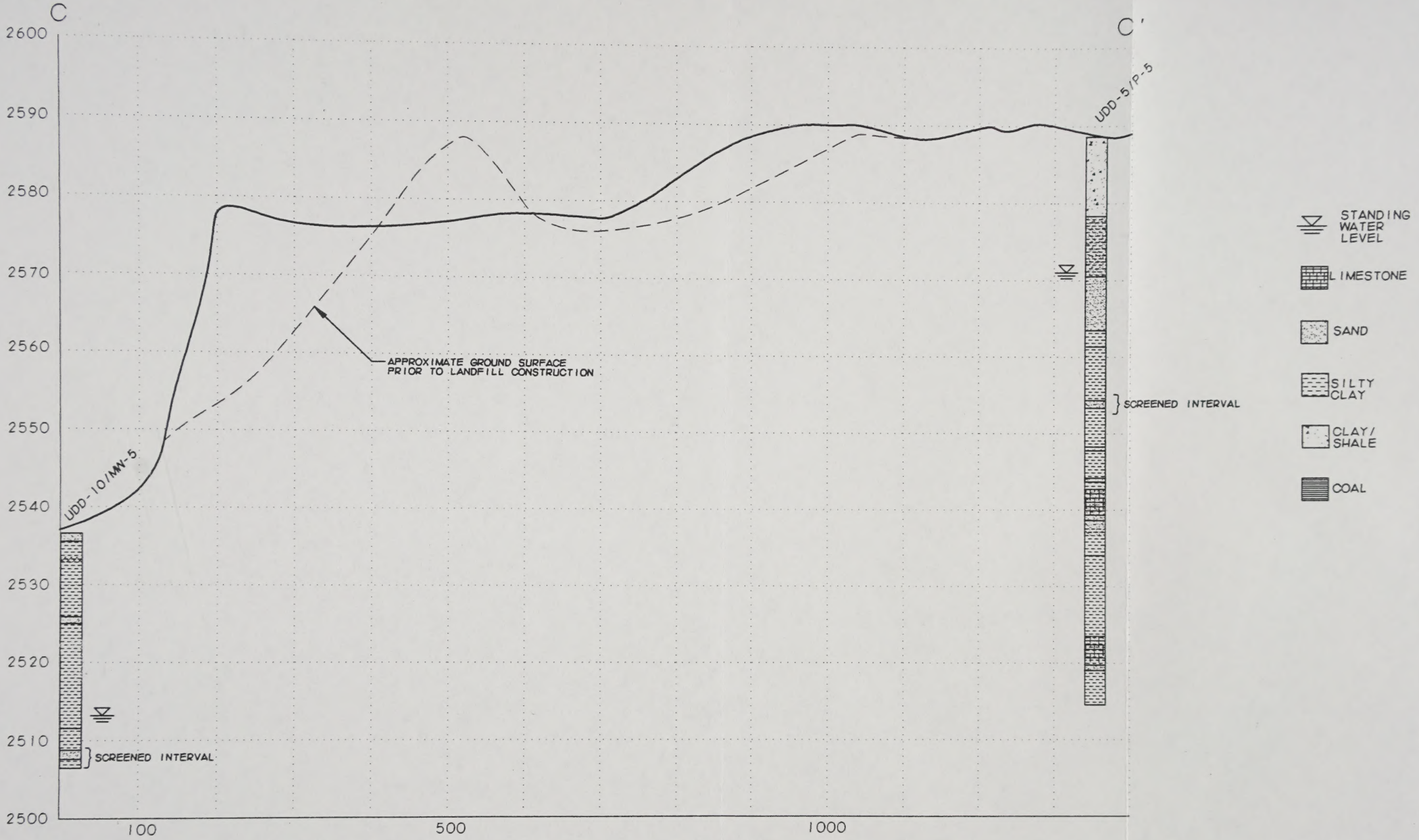

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Figure 4. Geologic cross section from C to C' at Unified Disposal District landfill, Havre, Montana.

concept. While depth to ground water appears to be well outside the range of concern in most places, the nature of the uppermost substrate appears to be inadequate for liner construction. The silt and clay of the Judith River formation, which underlies glacial material at depths ranging from 20 to 30 feet, is probably adequate for such an application,but would require too much excavation to be cost-effective. Since the use of this area would require significant re-design of the physical and operational plans, and since there is adequate space in the existing land fill for many more years of usage, plans for use of the expansion area have been suspended by Unified Disposal District officials for the time being. Future use of the area is not being ruled out, however, and drill cuttings, samples, and documentation of this investigation shall be retained by the Unified Disposal District until such time as the site is reconsidered or abandoned for use as a landfill.

RESPONSE TO MSHWB REVIEW

The following section is an item-by-item response to those points not addressed in the Damschen & Associates, Inc. April 21, 1992 response to the MSHWB review of March 3, 1992. Both of these correspondences may be found in Appendix A of this report. Again, some items herein might be considered academic at this point in time, in light of the changes in the hydrogeological characterization of the site and the different interpretation of the aquifers targeted for monitoring.

7. Page 7, Section E

The shallow groundwater potentiometric map has been redrawn and hopefully is more clear. This map is presented as Figure 1. Please note that the contours south of the landfill in the area of the drainage ditch have been truncated or removed. This is because the aquifer host has been removed in this area and the water now surfaces on the southern side of the ditch.

It is not clear that the potentiometric gradient of the "bedrock" aquifer is to the NE. The potentiometric surface indicates that the Milk River is a gaining stream in the region of the landfill and that the river is being recharged by the aquifer in which the wells were completed (Plate 1 of Damschen & Associates, Inc., 1991). Flow lines drawn perpendicular to the potentiometric contours show a north to northwest flow in the immediate vicinity of the landfill. If this is so, the water in the observation and shop wells occurs down gradient and at great depth below the present landfill. As stated in the MSHWB review, "they are not screened in the shallow aquifer." New data are now available that do not resolve this question, but change the emphasis of the targets to be monitored.

Essentially, there is still no evidence that these two wells are completed in the same aquifer. In fact, the nature of the hydrostratigraphy revealed by the additional investigation would lead to the conclusion that these two wells were completed in different sand bodies that are not vertically connected. There is also the possibility that the shop well was drilled into an aquifer that is discharging into the Milk River alluvial aquifer in such a manner that the apparent static water level is higher than that in the observation well. It is also worthy of note that the bottom of the aquifer penetrated by each well was not encountered and that the observation well is screened through two relatively permeable zones. Thus, another possibility is that water under pressure head in the observation well is rising from a lower zone and exiting through the higher zone, thus providing an aberrant water level.

The author intends to leave the discussion at this point, because it appears that the dissertation is academic. The findings of the additional field investigation make further discussion of no practical value to the protection of the ground water at the site.

RESPONSE TO REVIEW REVIEW

The following section is an attempt to deal with the points that arose in the Review in the Environmental Assessment, Jan. April 21, 1982 response to the MSTOW review of March 3, 1981. Item of these organizations may be found in Appendix 6 of this report. Again, some items have been made considered irrelevant at this time, in light of the Interim in the organizational reorganization of the site and the different interpretation of the aquatic impact for monitoring.

7. Page 7, Section E

The alluvial gravels are permeable and have been leaching and hopefully is over water. This map is present of a Figure 1. Please note that the unknown wall of the landfill in the area of the drainage ditch have been uncovered or removed. This is because the results have has been removed in this area and the water now partners on the southern side of the ditch.

It is not clear that the pseudomonads problem at the "bottom" aquifer is in the NE. The pseudomonads in surface indicates that the Salt River is a gaining stream in the region of the landfill and that the river is being recharged by the aquifer in a sixty-foot wide area.

Page 1 of Table 1 of Data indicates a groundwater flow. Does that mean perpendicular to the vertical hydraulic gradient, or a north to southeast flow in the northern section of the landfill. It has to be the water in the observation and deep wells contain chemicals and at some depth below the present landfill. As stated in the MSTOW review, "they are a source in the shallow aquifer." Why can't we have evidence that is not revealed the question, but change the emphasis of the target to be monitored.

Seemingly, there is still no evidence that these two wells are connected to the same aquifer. In fact, the nature of the hydrogeology revealed in the site local investigation indicates that is not the case that these two wells were constructed in different and widely that are not well connected. There is also the possibility that the deep well was drilled between the aquifer that is discharging into the Salt River allowing aquifer to seek a manner that the aquifer that is deeper than that is the deep flow well. It is also worthy of note that the solution of the aquifer presumed by most well was not a continuous and that are scattered as well is seen and through into relatively permeable zones. Thus, another possibility is that water from the aquifer feed in the observation well is from a river and not the aquifer as the observation well is from a river.

The author wants to leave the discussion at this point. Because it reveals the discussions is excluded. The purpose of the additional field investigation was to further educate of a practical view to the protection of the ground water at the site.

8. Page 10, Section 2

The regional geologic conclusions in this section probably can not be extended to this specific site with the data given and its date of publication. The most recent field investigations do not collaborate a regional dip to the northeast.

10. Page 21, Section B

As Figure 1 of the 1991 report demonstrates, the groundwater flow is not determined by the regional dip since flow is not to the northeast but to the north to northwest. As previously noted, no evidence of a regional dip clearly exists at the site. Since flow is to the north to northwest, and since water flows toward and recharges the Milk River, that the shop well static water level is higher than the static water level of MW-2 may well be an expected requirement. Flow lines become shallower with regard to the surface as they discharge into a stream. As noted in the above response to Item 7, the deeper "bedrock" aquifer is not of primary concern. New shallow aquifer monitoring wells have been installed and sampled and will be addressed later in this document.

The aquifer transmissivities were obtained from Walton (1987 and 1989) and are literature values. The formulas are attached in Appendix A at the end of this document.

11. Page 24, Section E

The calculations were performed assuming 100% shale and with no consideration of any time considerations for the vertical component of flow through the sand units. Therefore, if a flow rate through 65 feet of sand is considered using the same literature source for hydraulic conductivity, the total travel time is increased by 16 years. Thus the total estimated travel time becomes 181 years (Appendix A). The estimate above for 165 feet of shale and 65 feet of sand assumes these beds are continuous. It is true that lateral migration is possible in this environment. However, it was concluded that the specific prediction of travel time within sediments originating in a fluvially-dominated deltaic environment was problematic. Since the primary concern of the MSHWB at the time was the contamination of the "bedrock" aquifer over 200 feet below the surface, it was concluded that the most conservative approach was to calculate a "straight-line" travel time through only the most impermeable strata. Thus, the travel time estimate significantly overestimates the actual lithology thickness and corresponding conductivity present. The estimated time of travel to the "bedrock aquifer" may well be also lengthened significantly in view of the complex stratigraphy and potential for lateral migration. It must be agreed that the discontinuous nature of the deposits at the site would probably allow for a convoluted pathway to the "bedrock aquifer". A tortuous migration path would only serve to lengthen the time of travel. In general, it is clear that clay predominates at this site over sand units and the 180 year estimate is surely greatly positively biased and overestimated.

8. Page 18, Section 2

The regional geologic conclusions in this section probably can not be compared to this specific site with the data given and its date of publication. The most recent field investigations do not call/conclude a regional dip to the northeast.

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The aquifer transmissivities were obtained from Walton (1987 and 1989) and are estimate values. The formulas are attached in Appendix A at the end of this document.

11. Page 24, Section E

The calculations were performed assuming 100% sat's and with no consideration of any time consideration for the vertical component of flow through the sand units. Therefore, if a flow rate through 55 feet of sand is considered using the same literature source for hydraulic conductivity, the total travel time is increased by 16 years. Thus the total estimated travel time becomes 181 years (Appendix A). The estimate above for 165 feet of clay and 55 feet of sand assumes these beds are continuous. It is true that lateral migration is possible in this environment. However, it was concluded that the specific prediction of travel time within sediments originating in a fluvially-dominated deltaic environment was problematic. Since the primary concern of the MW11W1 at the time was the contamination of the "bedrock" aquifer over 200 feet below the surface, it was concluded that the most conservative approach was to calculate a "worst-case" travel time through only the most impermeable strata. Thus, the travel time estimate significantly overestimates the actual lithology thickness and corresponding conductivity present. The estimated time of travel in the "bedrock aquifer" may well be also lengthened significantly in view of the complex stratigraphy and potential for lateral migration. It must be agreed that the elements/masses of the chemicals at the site would probably allow for a convoluted pathway to the "bedrock aquifer". A vertical migration path would only serve to lengthen the time of travel. In general, it is clear that clay predominates at this site over sand units and the 120 year estimate is surely greatly positively biased and overestimated.

Our further response to the lack of information regarding lateral flow paths was to explore the hydrostratigraphy proximal to the fill area. This was accomplished by drilling an additional 14 test borings and excavating a series of exploration pits along the southern boundary of the existing landfill.

12. Page 29, Table 3

Given the following data extracted from the Table 3 of the report (Damschen & Associates, Inc, 1991):

Test Pit	Elevation (feet, MSL)	Depth to Water (feet)
TP-5	2592	19
TP-16	2594	17
TP-27	2530	20

it can be seen that test pit TP-16 is up gradient from Test pit 27. Since TP-5 is within 2 feet elevation and separated by only 400 feet, it can be assumed that TP-5 is also up gradient from TP-27.

No duplicates were run on samples from Test pit 16. The only duplicates run were those for a sample for MW-2. In looking at these data sheets, all values were less than 10% for the relative percent difference except for sulfate. If greater than ten percent is considered as a poor recovery, then a "poor recovery" for only one analyte should not discredit all of the analytical results.

13. Appendix E

Transcription errors in TP-1 and TP-24 have been changed and are noted in Appendix A of this document.

The first set of symbols used in the tables of test pits are rough visual approximations of the USC system of soil description (Appendix A). This system requires sieve analysis to actually designate the soils, but universally visual and textural names are applied in the field based on the USC system.

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12. Page 29, Table 2

Given the following data extracted from the Table 2 of the report (Dames & Moore, Inc, 1991):

Test Pit	Elevation (feet, MSL)	Depth to Water (feet)
TP-5	2592	19
TP-16	2594	17
TP-27	2590	20

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Transcription errors in TP-1 and TP-24 have been changed and are noted in Appendix A of this document.

The first set of symbols used in the tables of test pits are rough visual approximations of the USC system of soil description (Appendix A). This system requires more analysis to accurately designate the soils, but universally visual and textural names are applied in the field based on the USC system.

The second set of symbols are informal correlation symbols used in our attempts (unsuccessful) to correlate individual strata at the site.

ADDITIONAL HYDROGEOLOGICAL AND SOILS INVESTIGATION

Introduction

In response to the urgent need to develop a Ground Water Monitoring Network and associated Sampling and Analysis Plan (SAP), Damschen & Associates, Inc., submitted a Work Plan to the MSHWB. An extensive investigation was undertaken in April of 1993 consisting of drilling test borings and installing piezometers and monitoring wells. Slug tests were subsequently performed in each new well that intercepted water. In the interest of expediency, the Bureau allowed Damschen & Associates, Inc. to submit a preliminary SAP and proceed with the ground water monitoring, which took place in late July of 1993. The results of all of these studies follows.

Methods and Materials

Borings were drilled using a Garner-Denver table drive drilling rig provided by Sharp Drilling of Sidney, Montana. All holes were spudded with a 5.75-inch tri-cone rotary bit to a depth of 20 feet and completed using a three-step blade bit. Samples were collected on five-foot intervals.

Holes not completed as piezometers or monitoring wells were plugged with medium pellet bentonite within any water-bearing zone and with #8 granular bentonite throughout unsaturated zones to within three feet of the surface, whereupon native soil was used as fill to the ground surface. In completely dry holes, where no free water was intercepted, a mixture of cuttings and #8 bentonite was used to plug the hole. The well logs and Montana Department of Health and Environmental Sciences well completion forms are attached in Appendix B.

Piezometers and monitoring wells alike were completed to all required procedures delineated by the Board of Water Well Contractors and the MSHWB, with the exception that the piezometers were not completed with a concrete pad around steel surface casing. Instead, #8 granular bentonite was packed around five-foot lengths of five-inch-diameter Schedule 80 PVC protective casing. The monitoring wells were completed with decontaminated two-inch-diameter Schedule 40 PVC with factory-cut 0.010-inch slots of various screen lengths, depending upon the aquifer thickness. Filter pack sand was filled to one foot above the top of the screen on all wells and piezometers. The wells were finished with four- or six-inch diameter square steel protective casing set in two-foot-square concrete pads. Protective posts were also set in the concrete pads.

The hydraulic conductivity of the aquifers in which monitoring wells were completed were determined using slug-out tests. The resultant data were used with the formula modified from Hvorslev as presented in Fetter (1988):

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Holes not completed as piezometers or monitoring wells were plugged with medium yield bentonite within any water-bearing zone and with #3 granular bentonite throughout unsaturated zones to within three feet of the surface, whereupon native soil was used as fill to the ground surface. In completely dry holes, where no free water was encountered, a mixture of cuttings and #3 bentonite was used to plug the hole. The well logs and Montana Department of Health and Environmental Sciences well completion forms are attached in Appendix B.

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The hydraulic conductivity of the aquifers in which monitoring wells were completed were determined using slug test. The resultant data were used with the formula modified from Hvorslev as presented in Fetter (1993).

$$K_{ft/day} = \frac{r^2 \ln(L/R)}{2LT_o}$$

where

K is hydraulic conductivity
r is the radius of the well casing
R is the radius of the well screen
L is the length of the well screen
T_o is the time it takes for the water level to rise or fall 37 percent of the initial change.

The raw data sheets, calculation sheets, and graphs used to determine the hydraulic conductivity of each aquifer are included in Appendix D.

The monitoring wells were sampled according to the protocol outlined in the SAP for the facility. The analytical reports are included in Appendix E.

Results and Discussion

Test Borings. The locations of test borings and associated piezometer and monitoring well completions are included on Plate 1, in the attached pocket. All borings were initially assigned a prefix of "UDD" for in-house records. Borings in which piezometers were completed were re-assigned with the prefix "P". Likewise, borings completed as monitoring wells were reassigned with "MW" prefixes. Holes that were plugged immediately after drilling retained the "UDD" prefix. All nomenclature is included on the maps, well logs and DHES well completion forms.

As the well logs (Appendix B) and the cross sections (Figures 2, 3 and 4) show, significant measurable ground water was discovered in strata 100 to 200 feet above the "bedrock" aquifer that was previously discussed as the target for ground water monitoring. In fact, numerous zones containing measurable free water were discovered.

Glacial Aquifer. The shallowest water-bearing zone was discovered in a thin sliver of glacially-derived sand and gravel lying between the fill area and the drainage ditch that was excavated on the south side of the facility during 1992. One monitoring well and one piezometer were installed in this zone (MW-7, P-4 on Plate 1). Due to caving of the hole, the completion of these two installations was difficult, and the monitoring well was initially considered to be of little value since it appeared that it was not completed below the water table.

$$K_{max} = \frac{r^2 \ln(R/r)}{2LT_o}$$

where

K is hydraulic conductivity
r is the radius of the well casing
R is the radius of the well screen
L is the length of the well screen
T_o is the time it takes for the water level to rise or fall 37 percent of the initial change.

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The presence of water within these sediments was surprising and of some concern, since it is immediately proximal to the waste fill area. It was decided that an additional investigation of this area was warranted. This subsequent investigation in July of 1993 revealed that neither the well nor the piezometer contained any free water. Four test pits were excavated in this sand and gravel deposit (Figures 2, 3 and 4; Appendix B; Plate 1) and no free water was found. The stratigraphy revealed relatively coarse, permeable deposits of sand, apparently of Pleistocene age, lying atop a southward-dipping clay beds belonging to the Judith River formation.

The presence of water in the upper formation can be explained by seasonal surface infiltration seeping into the coarse sediments and settling atop the clay of the Judith River formation. This moisture appears to migrate toward the drainage ditch as a result of the southward dip of the top of the Judith River formation. The very small amount of recharge to this zone in conjunction with the southward-dipping hydraulic barrier provided by the clay of the Judith River formation lead to the conclusion that the moisture within the glacial sediments is of minor consequence to the landfill operations.

This also sheds light on the reason for the intermittent nature of the seepage that was observed on the southern side of the fill area in 1989. Since the permeable glacial sands lie upon a southward-dipping aquiclude, it seems that only extraordinary precipitation events would allow the aquifer to "fill up", so to speak, and spill over the lip of the aquiclude. This would result in the intermittent seeps. This hypothesis is supported by the magnitude of the precipitation events during the time period prior to the appearance of the seeps, in conjunction with the fact that former pasture south of the landfill was tilled (Larry Broere, personal communication).

Multiple Perched Aquifers in the Judith River Formation. As many as five individual perched aquifers were delineated during the investigation of the sediments of the Judith River formation. This formation is Cretaceous in age and represents a regression bounded above, below and to the west by marine shales. The dominance of silt and clay transected by sand bodies, along with the general lack of lateral continuity of strata on the small scale are strong indicators that these predominately unconsolidated sediments occur as a result of deposition within a fluvially-dominated deltaic and/or estuarine environment. Other important features observed in outcrop and in drill cuttings include shell beds, which most likely represent channel lag, and ample gypsum, both disseminated and as discrete beds. Other related evaporite minerals were present, but remain unidentified. It is thought that halite and various borates may be present in some of the sediments, but the fine-grained nature of these apparent salts precluded precise identification in the field. The presence of these minerals is indicative of high rates of evaporation in areas that were intermittently flooded with fresh and/or brackish waters.

Structurally, the most recently-drilled boreholes support the initial findings of silt and clay beds punctuated by bodies of fine sand. Correlations are next to impossible to complete over

The presence of water within these sediments was surprising and of some concern, since it is immediately proximal to the waste fill area. It was decided, that an additional investigation of this area was warranted. This subsequent investigation in July of 1993 revealed that neither the well nor the piezometer contained any free water. Four test pits were excavated in fine sand and gravel deposits (Figures 2, 3 and 4; Appendix B). While ice and no free water was found. The stratigraphy, revealed relatively coarse, permeable deposits of sand, apparently of Pleistocene age, lying atop a southward-dipping clay bank belonging to the Judith River formation.

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Multiple Perched Aquifers in the Judith River Formation. As many as five individual perched aquifers were detected during the investigation of the sediments of the Judith River formation. This formation is Cretaceous in age and represents a regression from above, below and in the west by marine shales. The alternance of silt and clay interspersed by sand bodies, along with the general lack of lateral continuity of strata on the small scale are strong indications that these predominantly unconsolidated sediments occur as a result of deposition within a fluvially-dominated delta and/or estuarine environment. Other important features observed in outcrop and in drill cuttings include shell beds, which most likely represent channel lag, and large, pyrites, both disseminated and as concretions. Other related stratigraphic elements were present, but remain unidentified. It is thought that lahar and various bentonite seams may be present in some of the sediments, but the line-drawing nature of these sediments also precluded proper identification in the field. The presence of these minerals is indicative of high rates of sedimentation in areas that were intermittently flooded with fresh ashfall bearing waters.

Accordingly, the more recently-drilled boreholes support the initial findings of silt and clay beds punctuated by lenses of fine sand. Correlations are next to impossible to complete over

more than a few feet, which is to be expected in an environment that was controlled by shifting channels and strongly evaporative climatic conditions. A good example of the rapid lateral changes in stratigraphy is demonstrated by comparing the logs of UDD-8 (MW-7) and UDD-9 (MW-3). A hard, resistant silty limestone (or carbonate-cemented siltstone) is found in UDD-8 at a depth of about 18 feet but is totally absent in UDD-9, which is about 20 feet away. Also, the thickness of a sand bed found approximately 25 feet beneath the surface differs in thickness by several feet between borings. This is typical of distributary channel deposits in an environment dominated by mud flats. The multiple perched aquifers found within the Judith River formation are, therefore, to be expected in view of the depositional environment.

Most of the saturated zones intercepted lie below the lowest level of waste fill at the site. One exception to this is to be found in monitoring well MW-3 (UDD-8). The base of this saturated zone of fine sand lies at an elevation of 2,542 MSL. The ground level of MW-5 (UDD-10) near the western entrance is approximately 2,537 feet MSL, which is the lowest elevation at which waste has been deposited. This sand bed was intercepted at MW-3 over 900 feet from any area where waste would have been deposited on the former land surface at the elevation of the base of the aquifer. In addition, this sand bed does not appear at the surface in the vicinity of the western end of the landfill, so it apparently is not continuous in this direction. No saturated zones were detected at this elevation in any other boring and there is no indication in previous reports of any seeps occurring at this elevation anywhere in the vicinity of the fill area.

The other saturated zone that lies above the base of the waste fill area was intercepted in P-5 (UDD-5). This zone comprises a thin sand bed bounded above and below by clay (Figure 4; Appendix B). As with the aquifer at MW-3, this saturated zone was encountered at the eastern end of the landfill and the lowest elevation of waste deposition lies at the western end of the landfill. The well lies nearly 1,000 feet laterally from the nearest point at which waste would have been deposited at similar elevation on the former land surface. As with most of the other aquifers at the site, this zone was not intercepted within any other boring.

Neither of these aquifers is thought to intercept the waste fill area. There is no historical evidence of either of these aquifers surfacing within the valley that now comprises the landfill. Also, there is no evidence that these aquifers are continous beneath the landfill; aquifers were not intercepted at similar elevations within any other drill holes.

The aquifer screened at MW-5 (UDD-10) lies within 35 feet of the bottom of the western-most portion of the base of the waste fill area. Water in this aquifer is under six feet of hydraulic head and exhibits a hydraulic conductivity of 1.8×10^{-5} cm/sec (Table 1). An unsuccessful attempt was made to intercept this aquifer approximately 200 feet to the north, at the point denoted on Plate 1 as UDD-11. Aquifers at similar elevations were intercepted at MW-4 (UDD-13) and MW-6 (UDD-18), but it is difficult to differentiate them on the basis of structure or simple elevation. Chemically, water from MW-5 more closely resembles that sampled at MW-6. If these two aquifers are connected, then MW-5 is

more than a few feet, which is to be expected in an environment that was controlled by similar climatic and strongly evaporative climatic conditions. A good example of the rapid lateral changes in stratigraphy is demonstrated by comparing the logs of UDD-8 (MW-2) and UDD-9 (MW-3). A hard, resistant silty limestone for carbonate-cemented silt/sand is found in UDD-8 at a depth of about 18 feet but is totally absent in UDD-9, which is about 20 feet away. Also, the thickness of a sand bed found approximately 32 feet beneath the surface differs in thickness by several feet between borings. This is typical of alluvium-filled deposits in an environment dominated by mud flats. The multiple cemented aquifers found within the Indian River formation are, therefore, to be expected in view of the depositional environment.

Most of the saturated zones intercepted lie below the lowest level of waste fill at the site. One exception to this is to be found in monitoring well MW-3 (UDD-8). The base of this saturated zone of fine sand lies at an elevation of 2,547 MSL. The ground level of MW-5 (UDD-10) near the western cover area is approximately 2,537 feet MSL, which is the lowest elevation at which waste has been deposited. This sand bed was intercepted at MW-3 over 900 feet from any area where waste would have been deposited on the former land surface at the elevation of the base of the aquifer. In addition, this sand bed does not appear at the surface in the vicinity of the western end of the landfill, so it apparently is not continuous in this direction. No saturated zones were detected at this elevation in any other boring and there is no indication in previous reports of any seepage occurring at this elevation anywhere in the vicinity of the fill area.

The other saturated zone that lies above the base of the waste fill area was intercepted in P-3 (UDD-5). This zone comprises a thin sand bed bounded above and below by clay (Figure 4, Appendix B). As with the aquifer at MW-3, this saturated zone was encountered at the eastern end of the landfill and the lowest elevation of waste deposition lies at the western end of the landfill. The well lies nearly 1,000 feet laterally from the nearest point at which waste would have been deposited at similar elevation on the former land surface. As with most of the other aquifers at the site, this zone was not intercepted within any other boring.

Neither of these aquifers is thought to intercept the waste fill area. There is no historical evidence of either of these aquifers underlying within the valley that now comprises the landfill. Also, there is no evidence that these aquifers are continuous beneath the landfill, aquifers were not intercepted at similar elevations within any other drill holes.

The aquifer encountered at MW-5 (UDD-10) lies within 35 feet of the bottom of the western most portion of the base of the waste fill area. Water in this aquifer is under six feet of hydraulic head and exhibits a hydraulic conductivity of 1.8×10^{-4} cm/sec (Table 1). An unsuccessful attempt was made to intercept this aquifer approximately 300 feet to the north at the point denoted on Plate 1 as UDD-11. Aquifers at similar elevations were intercepted at MW-4 (UDD-12) and MW-6 (UDD-10), but it is difficult to differentiate them on the basis of structure or simple elevation. Certainly, water from MW-5 seems closely resembles that encountered at MW-6. If these two aquifers are connected, then MW-5 is

Table 1. Hydraulic conductivities of aquifers in which monitoring wells were completed, Unified Disposal District landfill, Havre, Montana.

Well	K (ft/day)	K (cm/sec)	SWL (feet MSLD; 7/25/93)
MW-1	not measured		
MW-2	not measured		188.5
MW-3	321.3	1.13×10^{-1}	43.08
MW-4	21.3	7.52×10^{-3}	90.68
MW-5	375.8	1.32×10^{-1}	23.21
MW-6	309.4	1.09×10^{-1}	88.81
MW-7	dry		

hydraulically down-gradient from MW-6. There is considerable uncertainty, however, that MW-5 and MW-6 are completed within the same aquifer, due to the discontinuous nature of sand bodies within the Judith River formation. These wells are nearly 950 feet apart, and at least two holes were drilled to the depths of these aquifers (UDD-7 and UDD-11, Plate 1; Appendix B) and no free water was encountered. A fairly thick sand body was intercepted in UDD-7 between 2,508 and 2,518 feet MSL, but no free water was detected. As noted previously, UDD-11 was drilled about 200 feet north of MW-5 but the target aquifer was not found.

Recharge and Discharge. All of the drilling information and associated hydrological measurements point toward the existence of numerous perched, confined aquifers beneath the landfill. It was simply imprudent to construct a ground-water map for the site, since the lateral extent of any single aquifer and the interconnectedness between aquifers is in question. An interesting feature of these aquifers is that they are all under considerable head (Figures 2, 3 and 4; Appendix B). The hydraulic conductivity of these sand aquifers is generally around 1×10^{-1} cm/sec (283 feet/day; Table 1). The question arises, then, as to what mechanism allows these highly transmissive perched aquifers to maintain hydraulic head values equal to twice the aquifer thickness or more. Several possibilities arise.

First, given the general lack of proven lateral continuity of the sand bodies, it is hard to imagine that the recharge so greatly exceeds the transmissive capacity of the saturated zones that significant pressure head can develop. Three of the four screened aquifers have hydraulic conductivities in the range of 1×10^{-1} cm/sec (283.5 ft/day) and the aquifers encountered averaged about two feet in thickness. These sand bodies can rarely be traced over a lateral distance of thirty to forty feet in more than one direction. Using this information as guideline, one can envision as typical a two-foot-thick, 20-foot-wide aquifer beneath the site, which can theoretically discharge 1,134 cubic feet per day at a hydraulic gradient of 1. Assuming that there are multiple aquifers passing under the site, a recharge area supplying several thousand cubic feet per day must be established in order to account for the pressure heads observed. There is a small pond lying about 1,600 southeast of the facility that could supply significant recharge, but both stream and the pond are seasonal in nature and lie more than 10 feet below the nearest screened aquifer at P-5 (UDD-5). This pond is about 400 feet long, 75 feet wide and averages five feet in depth, which is large enough to supply any one of the known aquifers for about a third of a year, under the assumptions outlined above. However, discharge at the base of the earthen berm that serves as a dam was observed to be essentially equal to the inflow to the pond, which was on the order of a few liters per minute. Therefore, it is unreasonable to assume that the aquifers underlying the landfill are recharged beyond their transmissive capacity to a point where pressure head of several times the thickness of the aquifer can develop.

Perhaps a more plausible hypothesis is that the pressure head observed in the aquifers occurs because of the truncation or lateral thinning of the sand bodies, resulting in zones of greatly reduced hydraulic conductivity. Such physical changes in an aquifer would act as a hydraulic

hydraulically down-gradient from MW-6. There is considerable uncertainty, however, that MW-3 and MW-6 are completed within the same aquifer, due to the discrepancies found in rock bodies within the Indian River formation. These wells are nearly 850 feet apart, and at least two holes were drilled in the depths of these aquifers (UDD-7 and UDD-11, Plate 1: Appendix B) and no free water was encountered. A fairly thick sand body was encountered in UDD-7 between 2,305 and 2,315 feet MSL, but no free water was detected. As noted previously, UDD-11 was drilled about 300 feet north of MW-3 but no target aquifer was not found.

Recharge and Discharge. All of the drilling information and associated hydrological measurements point toward the existence of numerous perched, confined aquifers beneath the landfill. It was simply impudent to construct a ground-water map for the site, since the lateral extent of any single aquifer and the interconnectedness between aquifers is in question. An interesting feature of these aquifers is that they are all under considerable head (Figures 2, 3 and 4: Appendix B). The hydraulic conductivity of these sand aquifers is generally around 1 x 10^{-5} cm/sec (Hill Research, Table 1). The question arises, then, as to what mechanism allows these highly transmissive perched aquifers to maintain hydraulic heads values equal to twice the aquifer thickness or more. Several possibilities arise.

First, given the general lack of proven lateral continuity of the sand bodies, it is hard to imagine that the recharge so greatly exceeds the transmissive capacity of the saturated zones that significant pressure head can develop. Three of the four screened aquifers have hydraulic conductivities in the range of 1 x 10^{-5}cm/sec (200.5 ft/day) and the aquifers encountered averaged about two feet in thickness. These sand bodies can rarely be traced over a lateral distance of thirty or forty feet in more than one direction. Using this information as guidance, one can envision as typical a two-foot-thick, 20-foot-wide aquifer beneath the site, which can theoretically discharge 1,234 cubic feet per day at a hydraulic gradient of 1. Assuming that there are multiple aquifers penetrating under the site, a reasonable area supplying several thousand cubic feet per day must be established in order to account for the pressure heads observed. There is a small pond lying about 1,000 northeast of the facility that could supply significant recharge, but both stream and the pond are situated in marine and lie more than 10 feet below the nearest screened aquifer at P-5 (UDD-5). This pond is about 400 feet long, 75 feet wide and averages five feet in depth, which is large enough to supply any one of the known aquifers for about a third of a year, under the assumptions outlined above. However, discharge at the toeo of the earthen berm that serves as a dam was observed to be essentially equal to the inflow to the pond, which was on the order of a few liters per minute. Therefore, it is unreasonable to assume that the aquifers underlying the landfill are recharged beyond their transmissive capacity to a point where pressure head or several times the thickness of the aquifer can develop.

Perhaps a more plausible hypothesis is that the pressure head observed in the aquifers occurs because of the restriction or lateral thinning of the sand bodies, resulting in zones of greatly reduced hydraulic conductivity. Such physical changes in an aquifer would act as a hydraulic

barrier within a given sand body, allowing for an increase in pressure head up gradient. This may be demonstrated at MW-4, where the aquifer has a considerably lower hydraulic conductivity than the aquifer only a few feet above. The point here is that it is much easier to believe that the pressure head results from differential permeability values within a aquifer than to assume that it results from recharge that is significantly greater than discharge through an evenly permeable aquifer.

This still leaves the question of recharge. The aforementioned pond and the drainage in which it lies are likely zones of recharge for some of the aquifers that underlie the Unified Disposal District landfill. Aquifers that lie above the level of the pond may be recharged via downward migration of moisture trapped within the sandy glacial sediments that mantle the entire region. In fact, this seems a more likely source of recharge for most of the perched aquifers in the area, and would fit well into the characterization outlined above. This may be supported by the presence of seeps within the Judith River formation to the west of the landfill. The elevation of these seeps preclude recharge from the pond or stream valley that lies to the south. The only known source of moisture available to these seeps lies within the glacial sand. It is assumed that, if this is indeed the case, recharge to the deeper aquifers would be very slow, owing to the tortuous path required for water to find its way through many tens of feet of the complex sediment pile that makes up the Judith River formation.

The discharge point of these aquifers is not known. It may be that they discharge to the Milk River valley fill. The aquifers are difficult to trace, however, so that the actual direction of flow is unknown in most of them.

GROUND WATER MONITORING

Previous Work

Analytical results from surface runoff, water from an aquifer within the glacial sediments, and water from aquifers lying over 200 feet below the site are available in the previous site report (Damschen & Associates, Inc., 1991). These reports show that the ground water quality is very low, with high concentrations of ions. According the ARM 16.20.1002, these are all Class III waters, at best.

A request for additional hydrochemical information in the Bureau's March 3, 1992 letter was never clarified, but deserves mention here. The request was for "complete" analyses so that anion-cation balances could be performed. If the MSHWB analyte list is in question, then it is up to the Bureau to either include the appropriate ionic analyses in the regulations or request these analyses prior to sampling events, at location where it is warranted. It would be helpful if the reason for such calculations was clarified, as well.

There is some question regarding the value of a calculation of the ion balance at this site, as well as for the majority of other sites in the eastern and central portion of Montana. Lloyd and Heathcote (1985) state that attempting to determine laboratory or sampling error using this method "is only valid if all major ions are analysed. If there is an unanalysed ion there will be an ion balance error...If the analysis is dominated by a few ions, *for example saline waters dominated by Na^+ and Cl^-*, large errors in the other ions will produce only small errors in the ion balance" (italics inserted by author). A glance at the sodium and chloride values measured in waters at this site clearly demonstrate that, while the water samples may be electrically neutral, these Class III and Class IV waters verge on being saline. Many of the sediments contain very large quantities of evaporite-related minerals that are reflected in the ground water. Thus, it would seem that the ion balance method is an inappropriate method for use in determining laboratory error at this site.

Methods and Materials

Ground water samples were obtained, stored and shipped according to the Sampling and Analysis Plan submitted to the Bureau in July of 1993. The reader is referred to that document for methodology and materials employed for sampling.

Results and Discussion

The results of the first round of sampling at the most recently installed wells are included in Appendix E. The sample sites included all of the wells installed in 1993 with the exception of MW-7, which was found to be dry. At the request of the Bureau, MW-2 was also included in this most recent sampling event.

GROUND WATER MONITORING

Previous Work

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Results and Discussion

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The analyses reveal the presence of very poor quality water beneath the site. It is clear from the history of sampling and from the nature of the sediments that comprise the Judith River formation that the poor quality cannot be attributed to the presence of the Unified Disposal District landfill. All of the samples contain elevated levels of dissolved solids and various ions, including sodium, chloride, sulfate, calcium, magnesium and bicarbonate. The bulk of these are common constituents of water that is in contact with clay-rich, carbonate-rich and/or evaporite-bearing sediments (Bouwer, 1978; Krauskopf, 1979). Thus, it should not be surprising that high levels of sodium, chloride, sulfate, and so on, occur in ground water hosted by gypsum-bearing clay, marl, and other evaporite-bearing sediments. Some metals reported in MW-2 (Damschen & Associates, Inc., 1991) were not detected in the most recently-acquired sample. Some of these same metals, however, appear in some of the other aquifers. These metals, primarily lead, arsenic, iron, barium and manganese, tend to be concentrated in shales and clay-rich sediments (Krauskopf, 1979) and, again, it is not surprising that they occur in small quantities in this hydrogeological environment.

None of the samples revealed the presence of any volatile organic constituents in ground water at the site.

CONCLUSIONS

The Unified Disposal District landfill east of Havre, Montana is underlain by clay, silt, and sand of the Cretaceous-aged Judith River formation. This formation also contains small quantities of marl and coal. A thin wedge of Pleistocene-aged glacial sand and gravelly sand lies immediately adjacent to the southern edge of the landfill. These glacial deposits are ubiquitous in the area, and cover all of the highlands regionally.

Ground water was discovered in both formations, however the water in the glacial deposit is apparently seasonal in its occurrence, and does not appear to represent any serious threat to the landfill. This conclusion is arrived at as a result of data gathered during the drilling of three test borings and the excavation of four pits on the south side of the landfill just north of the drainage ditch that was constructed in the spring of 1992. These pits revealed the presence of a south-dipping clay bed directly underlying the glacial sand. It is presumed that any water that might be collected in the glacial sand will migrate laterally into the drainage ditch. The lack of water in either the piezometer or monitoring well in July of 1993 support this supposition.

Deeper ground water was discovered at several elevations within the Judith River formation. The aquifers comprise sand beds of varying thicknesses and unknown lateral continuity. The hydrogeological system is best characterized as a series of perched, confined sand aquifers within a larger body of sediments dominated by clay and silty clay. Some of the aquifers are probably connected, but defining that degree of interconnectedness is well beyond the scope of detection monitoring, given the complex hydrostratigraphy. Two of the aquifers occur at elevations above that of the lowest point of waste infilling, however there is no evidence to suggest that these aquifers intercept the waste fill area.

The hydrogeological system is characterized by Class III and Class IV waters available in very small quantities at depths ranging from 30 to 280 feet. The uppermost aquifers do not provide economically useful quantities of water. The deeper aquifers, which are discussed in a previous report (Damschen & Associates, Inc., 1991), have been shown to provide useful quantities of water, but analytical results revealed the very low water quality. None of the waters encountered to date can be applied to any significant municipal or commercial application, making their resource value minimal.

While it is remotely possible that some of the water within the Judith River formation is connate, it is more likely that recharge to the sand bodies occurs from surface infiltration and small drainages proximal to the landfill area. All of the deeper aquifers encountered are confined to some degree. This is probably indicative of fairly low recharge volumes entering the various sand bodies and migrating through zones of relatively lower permeability. These lower zones of permeability occur as a result of truncation of sand bodies or small-scale facies changes from channel or distributary bar sand deposits to lagoonal or back-water estuarine silt and clay.

CONCLUSIONS

The Unified Disposal District landfill east of Hoey, Montana is underlain by silty, silty sand of the Cretaceous-aged Judith River formation. This formation also contains small quantities of sand and coal. A thin wedge of Pleistocene-aged glacial sand and gravel lies immediately adjacent to the southern edge of the landfill. These glacial deposits are widespread in the area, and cover all of the highlands regionally.

Ground water was discovered in both formations, however the water in the glacial deposit is apparently seasonal in its occurrence, and does not appear to represent any serious threat to the landfill. This conclusion is arrived at as a result of data gathered during the drilling of three test borings and the excavation of four pits on the south side of the landfill last week of the drainage ditch that was constructed in the spring of 1992. These pits revealed the presence of a sandy-clippingy clay bed directly underlying the glacial sand. It is presumed that any water that might be collected in the glacial sand will migrate laterally into the drainage ditch. The lack of water in either the piezometer or monitoring well in July of 1993 supports this supposition.

Deeper ground water was discovered at several elevations within the Judith River formation. The aquifers comprise sand beds of varying thicknesses and unknown lateral continuity. The hydrogeological system is best characterized as a series of perched, confined sand aquifers within a larger body of sediments dominated by clay and silty clay. Some of the aquifers are probably connected, but defining the degree of interconnectedness is well beyond the scope of detection monitoring, given the complex hydrostratigraphy. Two of the aquifers occur at elevations above that of the lowest point of waste footing, however there is no evidence to suggest that these aquifers intercept the waste fill area.

The hydrogeological system is characterized by Class III and Class IV waters traversing very small quantities at depths ranging from 30 to 280 feet. The uppermost aquifers do not provide economically useful quantities of water. The deeper aquifers, which are discussed in a previous report (Hamilton & Associates, Inc., 1993), have been shown to provide useful quantities of water, but analytical results revealed the very low water quality. None of the waters encountered to date can be applied to any significant municipal or commercial application, making their resource value minimal.

While it is remotely possible that some of the water within the Judith River formation is connected, it is more likely that recharge to the sand bodies occurs from surface infiltration and small drainages proximal to the landfill area. All of the deeper aquifers encountered are confined to some degree. This is probably indicative of fairly low recharge volumes entering the various sand bodies and migrating through zones of relatively lower permeability. These lower zones of permeability occur as a result of truncation of sand bodies or small-scale facies changes from physical or diagenetic bar sand deposits to lagoonal or back-water carbonate silt and clay.

The results of the ground water sampling do not show any clear indication of contamination due to the presence of the landfill. What was revealed, however, was the overall poor quality of the naturally-occurring ground water, which is common to aquifers hosted within deposits dominated by marine and estuarine shale and clay. The presence of evaporative minerals within the sediment further degrades the natural quality of the ground water.

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Krauskopf, K.B., 1979, Introduction to geochemistry: McGraw Hill international series in the earth and planetary sciences, McGraw-Hill Book Company, New York, 617 p.

Lloyd, J.W. and Heathcote, J.A., 1985, Natural inorganic hydrochemistry in relation to groundwater, an introduction: Clarendon Press, Oxford, England, 296 p.

APPENDIX A. ATTACHMENTS FOR THE RESPONSE TO THE HYDROGEOLOGICAL ANALYSIS

DEPARTMENT OF
HEALTH AND ENVIRONMENTAL SCIENCES
Solid and Hazardous Waste Bureau
Solid Waste Program
STAN STEPHENS, GOVERNOR (406) 444-1430
STATE OF MONTANA
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RECEIVED
MAR 06 1992
DAMSCHEN & ASSOCIATES
FAX #(406) 444-1499

March 3, 1992

Clay Vincent, R.S.
Unified Disposal District
Hill County Courthouse
Havre, MT. 59501

SUBJECT: Review of Hydrogeologic Analysis for the Existing Sanitary Landfill, Unified Disposal District, Havre, Montana, October, 1991

Mr. Vincent:

We have reviewed your report and prepared the following comments and questions.

TEXT - GENERAL COMMENTS

The "Hydrogeologic Analysis for the Existing Sanitary Landfill (Havre, Montana)", prepared by Damschen and Associates, Inc. fulfills most of the State of Montana requirements for landfill application investigations. The report, however, contains several errors, omissions, and contradictions, which raises concern about the report findings and the conclusions. Many of the contradictions are fundamental in nature and affect the conclusions regarding ground water contamination.

SPECIFIC COMMENTS

1. Report Title. The report title reflects a hydrogeologic analysis for the existing landfill. The report is actually an analysis of the existing 25-acre landfill and a lateral expansion landfill located on an abutting 40 acres.

2. Table of Contents. Section IV(B(2)(d) entitled Blood Pit, is not included in the report, but appears in the table of contents. Appropriate text regarding the blood pit should be added to the report or the section should be deleted from the table of contents.

3. Page 3, Section 2, first paragraph. The second sentence in this paragraph states the investigation was conducted during a period of unusually high rainfall. To substantiate the claim, the report should compare local rainfall records for the investigation period to the historical average rainfall during the same period. Local climatological records should also be used to prepare a landfill water balance as an aid to assessing potential landfill leachate generation. Information should be given regarding a 24 hour/25 year storm event.

March 2, 1992

Clay Vinson, R.S.
United Disposal District
Hill County Courthouse
Havre, MT. 59501

SUBJECT: Review of Hydrogeologic Analysis for the Existing Sanitary Landfill, United Disposal District, Havre, Montana, October, 1991

Mr. Vinson:

We have reviewed your report and prepared the following comments and questions.

TEXT - GENERAL COMMENTS

The "Hydrogeologic Analysis for the Existing Sanitary Landfill" (Hydro Analysis), prepared by Gerchen and Associates, Inc. fulfills most of the State of Montana requirements for landfill application investigations. The report, however, contains several errors, omissions, and contradictions, which raise concern about the report findings and the conclusions. Many of the contradictions are immaterial in nature and affect the conclusions regarding water contamination.

SPECIFIC COMMENTS

1. Report title. The report title refers a hydrogeologic analysis for the existing landfill. The report is actually an analysis of the existing 25-acre landfill and a lateral expansion landfill located on an adjacent 40 acres.

2. Table of contents. Section IVH(1)(ii) entitled Blood Pit, is not included in the report, nor appears in the table of contents. Apparently the requesting the blood pit should be added to the report or the section should be deleted from the table of contents.

3. Page 3, Section 2, first paragraph. The second sentence in this paragraph states the investigation was conducted during a period of unusually high rainfall. To substantiate the claim, the report should compare local rainfall records for the investigation period to the historical average rainfall during the same period. Local climatological records should also be used to prepare a landfill water balance as an aid to assessing potential landfill leachate generation. Information should be given covering a 24 hour/72 year storm event.

4. Page 5, Section B, second paragraph. This paragraph describes the methods used to evaluate shallow ground water elevations on the south side of the site. The fourth sentence states that, to obtain ground water elevations, the measured depth to ground water was correlated to surveyed test pit elevations. Site surveys should determine the elevation of the top of the perforated pipe placed in each excavation to obtain accurate ground water elevation measurements.

   The fifth sentence states that the measured ground water elevation data were combined with data estimating elevation of ground water seeps on the cut slope in the active landfill area. The data were used to develop a ground water potentiometric surface map (Plate 2). However, this map does not appear to incorporate the ground water seep elevations. It is appropriate that the shallow ground water potentiometric surface be determined using all available data. The seep elevations should be surveyed and the survey data should be incorporated into the potentiometric surface map.

5. Page 7, Section E, first paragraph. The first sentence states that water samples were collected from standpipes in test pits 5, 16, and 27. Yet the test pit logs in Appendix E and the test pit symbols on Plate 2 indicate no water was detected in test pits 5 and 16. The report should explain this discrepancy. If water was detected in test pits 5 and 16, the pits' respective ground water elevations should be incorporated into the shallow ground water potentiometric surface map on Plate 2. Also, Appendix H presents water analysis results for test pits 16 and 27 only. Appendix H should present analyses for test pit 5, if pit 5 did contain water. Water analysis data for test pit 16 show total dissolved solids (TDS) of 13,000 milligrams per liter (mg/ℓ); sulfate of 7,910 mg/ℓ; and chloride of 645 mg/ℓ. The report should explain this difference in ground water quality between pits 16 & 27 if the water came from the same water bearing unit. Also, the water analyses presented should be complete so that anion-cation balances can be performed to check laboratory results.

6. Page 7, Section E, second paragraph. The first sentence states that water samples collected from test pits 16, 27, and the existing observation well were analyzed to evaluate contaminants which migrated through the landfill into shallow ground water. The shallow ground water potentiometric map, however, indicates the locations of test pits 5 and 16 are not directly downgradient of the landfill. The shop well and the observation well are screened in the bedrock aquifer not the shallow landfill aquifer. According to Plate 1, the potentiometric gradient of the bedrock aquifer is northeast. These two bedrock wells, therefore, are not downgradient of the present landfill and are not screened in the shallow aquifer. Another investigation should be performed to evaluate contamination which migrated through the landfill into shallow groundwater. The investigation should gather sufficient data to (1) determine the gradient of the shallow aquifer, (2) collect ground water samples from boreholes or monitoring screened in the shallow aquifer upgradient and downgradient of the bedrock aquifer, (3) determine the local gradient of the bedrock aquifer, (4) collect ground water samples from monitoring wells screened in the bedrock aquifer upgradient and downgradient of the present landfill, and (5) determine the vertical gradients and potential for hydrologic interconnection between the shallow aquifer and bedrock aquifer.

7. Page 7, Section E, third paragraph. This paragraph states water samples were collected from monitoring wells MW-1, MW-2, and the shop well and were analyzed for Resource Conservation and Recovery Act (RCRA) Subtitle D chemical parameters. The paragraph also states the purpose of the analysis was to evaluate the landfill's impact on the bedrock aquifer. The measured elevations of the ground water in these three wells indicate the potentiometric surface of the bedrock aquifer slopes to the southwest. There is insufficient data to determine whether leachate from the present landfill has impacted the bedrock aquifer. The shop well may not be suitable for use as a monitoring well because it may not be located upgradient or downgradient of the current landfill or the proposed landfill and is not suitable because it is located more than 1,000 feet from the present landfill boundary.

   The report should include sufficient data points to determine the gradient of the bedrock aquifer and provide analysis of water samples collected from monitoring wells upgradient and downgradient of the present landfill. According to Montana Code Amendment 75-10-207, Rule IV, a minimum of three downgradient monitoring wells and one upgradient monitoring well must be installed into the uppermost aquifer to monitor landfill leachate contamination in the aquifer. Plate 2 indicates that monitoring wells MW-1 and MW-2 are located more than 800 feet north and south, respectively, of the present landfill boundary. The downgradient wells should be located within close proximity of the landfill boundary. According to Title 40 Code of Federal Regulations (CFR) 258.40(d), the monitoring wells shall not be located more than 150 meters from the landfill boundary and shall be located on land owned by the owner of the landfill.

8. Page 10, Section 2, second paragraph. This paragraph describes structural geological features identified in the region and infers a site-specific conclusion. As described, the conclusions are not logical. The text should be revised, or a figure should be included in the report to illustrate the conclusion.

10. Page 21, Section B, third paragraph. The paragraph describes the hydrogeological interpretation of the bedrock aquifer at the site. The data in Table 1 indicate that the water-bearing interval in MW-2 and in the shop well have elevations of 2,394 feet and 2,396 feet, respectively. According to the information presented in the geological section, the bedrock dips to the northeast. This water-bearing interval is approximately on a strike line between these two wells. Yet the paragraph states the water bearing units in these wells are not connected. The report should be revised to address the apparent stratigraphic relationship of the water-bearing sandstone at these locations.

    The report also indicates that the bedrock aquifer is used downgradient of the site. The report, therefore, should include sufficient data to determine, with reasonable certainty, the gradient of bedrock ground water beneath the site and evaluate the potential impact of leachate from the present landfill on this aquifer. This paragraph summarizes the methods used to estimate the hydraulic properties of the bedrock aquifer. The text should include the field data used to estimate the hydraulic properties and the analytical formulae used to calculate transmissivity.

7. Page 7, Section 2, third paragraph. This paragraph states water samples were collected from monitoring wells MW-1, MW-2, and the sump well, and were analyzed for Resource Conservation and Recovery Act (RCRA) subtitle D chemical parameters. The paragraph also states the purpose of the sampling was to evaluate the landfill's impact on the bedrock aquifer. The measured elevations of the ground water in these three wells indicate no possible-flow surface of the bedrock aquifer above to the southeast. There is insufficient data to determine whether leachate from the present landfill has impacted the bedrock aquifer. The sump well may not be suitable for use as a monitoring well because it may not be located upgradient or downgradient of the current landfill or the proposed landfill and is not suitable because it is located more than 1,000 feet from the present landfill boundary.

The report should include sufficient data policy to evaluate the quality of the bedrock aquifer and provide analysis of water samples collected from monitoring wells upgradient and downgradient of the present landfill. According to Montana Code Annotated 75-10-727, Rule IV, a minimum of three downgradient monitoring wells and one upgradient monitoring well must be installed upon the approval applicant to monitor landfill leachate contamination in the aquifer. Wells 3 indicates that monitoring wells MW-1 and MW-2 are located more than 500 feet north and south, respectively, of the present landfill boundary. The monitoring wells should be located within close proximity of the landfill boundary. According to Rule 10 Code of Federal Regulations (CFR) 258.40(d), the monitoring wells shall not be located more than 150 meters from the landfill boundary and shall be located on land owned by the owner of the landfill.

8. Page 10, section 2, second paragraph. This paragraph describes structural geological features identified in the region and infers a site-specific correlation. As described, the conditions are not logical. The text should be reviewed, or a figure should be included in the report to illustrate the conclusion.

10. Page 11, section 2, third paragraph. The paragraph describes the hydrogeological interpretation of the bedrock aquifer at the site. The data in Table 1 indicates that the water-bearing formation in MW-2 and in the sump well have elevations of 3,324 feet and 3,325 feet, respectively. According to the information presented in the geological section, the bedrock dips to the southeast. This water-bearing interval is approximately on a straight line between these two wells. Yet the paragraph states the water bearing units in these wells are not connected. The report should be revised to address the apparent stratigraphic relationship of the water-bearing sandstone at these locations.

The report also indicates that the bedrock aquifer is used downgradient of the site. The report, therefore, should include sufficient data to determine, with reasonable certainty, the gradient of bedrock groundwater beneath the site and evaluate the potential impact of landfill leachate from the present landfill on this aquifer. This paragraph summarizes the methods used to estimate hydraulic properties of the bedrock aquifer. The text should include the field data required to estimate the hydraulic properties and the analytical formulas used to calculate transmissivity.

10. Page 23, Section D, first paragraph, continued. The text should also summarize the field methods used to measure the aquifer response to water removal. The text, for instance, should describe: (1) how the water was removed, (2) the volume of water removed, and (3) the water level measurement methods, frequency, and total number of measurements. The calculations should be appended to the report.

11. Page 24, Section E, fourth paragraph. This paragraph describes the vertical movement of water through the unsaturated sandstone bedrock beneath the site and states that the flow time through the sandstones can be ignored. The text considers unsaturated flow in the vertical direction only. In sedimentary sequences, unsaturated flow can be influenced by lithologic changes. According to the report discussion, the bedrock formation is a fluvial deposit. Typically, fluvial deposits contain sharp lithologic boundaries at the bottom of sand channels. The sand directly overlies the fine-grained sediment. If leachate were to enter a sandstone body under unsaturated conditions, it would flow vertically through the sandstone until it came in contact with the underlying shale, then it would migrate laterally and downgradient along the sandstone preferential flow path. The report should acknowledge the effect of preferential flow paths in the unsaturated zone. The calculations should not ignore transport through the sandstone intervals.

12. Page 27, Table 3. As noted earlier on Plate 2, test pit 5 is shown as dry. Table 3 contradicts this and no supporting laboratory analyses data are presented. Test pit 16 is also shown as dry on Plate 2, but is shown as upgradient (actually downgradient) and water analyses are provided. These contradictions, and the laboratory analyses for duplicate samples presented in Appendix I, lead one to question the water analyses from these 2 locations. See comment 6 recommendations.

13. Appendix E. This appendix contains the test pit logs. The log descriptions are very brief and are incomplete. For instance TP-1 describes the 11 to 12.7 foot interval as red, and the 12.7 to 15 foot interval as light. Numerous logs contain single letters in parentheses after the rock descriptions, yet the meaning of the letters is not defined. The logs should be revised to include complete soil or rock descriptions, and all symbols should be referenced or defined.

DRAWINGS - GENERAL COMMENTS (SHEETS 1 THROUGH 15)

No construction details are presented for leachate collection and treatment or gas migration monitoring and interception. These details should be provided following further analysis.

SPECIFIC COMMENTS

1. Sheet 2. No scale is given in this drawing. It is recommended that horizontal and vertical control be given for property pins. This sheet depicts test pit 5 with water; Plate 2 in the text notes it to be dry. Similarly, this sheet shows test pit 17 as dry; Plate 2 shows water. See specific comments 6 and 12 on the hydrogeologic analysis report.

10. Item 10, section 3, Plan parameters, discussion. The text should also summarize the local methods used to measure the actual production on each recovery. The text, for instance, should describe, (1) how the water was measured, (2) the volume of water measured, and (3) the value level measurement methods, frequency, and local method of measurement. The calculations should be appended to the report.

11. Page 24, section 3, Plans, narrative. This paragraph describes the vertical movement of water through the unsaturated pyroclastics between the site and strata that the flow takes through the saturated zone to the aquifer. The text describes unsaturated flow in the vertical direction only. In monolithic sequences, unsaturated flow can be initiated by lateral impede. Actually in the report discussion, the lateral flow is a fluvial deposit. Typically, fluvial discrete channels are lithologic boundaries at the bottom of bank sequences. The sand directly overlies the flow-plane sediment. It therefore has to drain a saturated body under unsaturated conditions. It would flow vertically through the sandstone until it comes in contact with the underlying shale, then it would migrate laterally and downgradient along the sandstone pyroclastic flow zone. The report should explain why the effect of preferential flow paths in the unsaturated zone. The calculations should use upgrade transport through the sandstone layering.

12. Page 27 Table 3. As noted earlier in Plans 2, case pit 8 is shown as dry. Table 3 concentrates this and on supporting laboratory analyses data are presented. Case pit 18 is also shown as dry as Plans 2, but is shown as porous (assumably downgradient) and water analyses are provided. Plans contradictions, and the laboratory analyses for duplicate analyses (shown in appendix C, look one to question the water analysis from Plans 2 laboratory. See comment 6 recommendations.

13. Appendix E. This appendix contains the test pit logs. The log descriptions are very brief and are inconsistent. For instance TP-1 describes the 0.0 to 12.7 foot interval as sand, and the 12.7 to 18 foot interval as silt. Numerous logs contain alternating patterns in parameters after the work descriptions. But the measure of the interval is not defined. The logs should be revised to include complete well or zone description, and all symbols should be referenced or defined.

Appendix - Water Quality Analysis (Sheets 1 through 18)

No construction details are presented for instance collection and treatment or the minerals monitoring and lysimeters. These details should be provided following further analysis.

Effluent Monitoring

1. Report. No mention is given in this drawing. It is recommended that horizontal and vertical control be given for property plan. This must compare each pit & with water) Plans 2 in the text notes it to be dry! warranty. This about about test pit 17 as dry; Plans 2 shows water. See specific comments 4 and 17 on the hydrogeologic analysis report.

2. Sheet 3. The natural gas pipeline noted probably has an easement. The gas line intersection coordinates with the property line should be noted. No perimeter fencing is noted on the drawing. An easement/title to the access road should be analyzed. The sheet shows a gate relocation and new access road on abutting private property. Also, access road construction details should be given. The sheet shows two surface water detention ponds. One reflects a dam height of approximately 20 to 25 feet and the other dam approximately 30 to 35 feet high. A site water balance should be completed. Surface water runoff calculations and pond sizing should also be completed and presented for review.

3. Sheet 5. This sheet indicates shallow ground water interception and conveyance to private property east of the landfill area. Surface drainage will also be conveyed across private property to the east. Ground and surface water should be collected and routed to the west on district property. No easterly surface water detention is shown. The final contours proposed result in slopes of ±10 percent for the existing landfill area. Erosion and slope stability analyses should be performed to determine the acceptability of these slopes. At the proposed ground water subdrain and gas line intersection, the contours indicate that the gas line is spanning the ditch. The contours should be revised. Similarly, the subdrain and gravel pit access road intersection contours should be changed. The current drawing assumes that the access road will be retained.

4. Sheet 6. This sheet shows the subdrain and gas line intersection to include a 100-foot corrugated metal pipe (CMP) and dike to retain the gas line. The saturated condition of these soils may make this dike unstable. The gas line company probably has an easement with which this plan must be consistent. The district, therefore, must have permission to construct as planned. The sheet indicates that the access road has been abandoned. This should be confirmed by those using the road. The subdrain will, as noted earlier, convey ground water (and surface water) to private property on the east. It is recommended that the subdrain grade be revised and all surface and ground water drainage be confined to district property. The subdrain, as depicted, varies in elevation from ±2,587 feet to ±2,575 feet. Ground water below these elevations will continue to migrate north through the existing landfill. This ground water should be intercepted or leachate collection provided below the existing landfill. Slopestake limits for the subdrain should be included on this sheet. The subdrain excavation will be in water and trench stability issues should be addressed.

5. Sheet 15. The existing ground water level is reportedly at an elevation of ±2,590 feet. The subdrain on Sheet 6 is at an elevation of ±2,587 feet to ±2,575 feet. The existing landfill contains trash below elevation ±2575 feet, which will continue to be saturated with the subdrain proposed. A method to prevent continued saturation of the trash should be presented.

Page Five

2. Sheet 1. The natural gas pipeline noted probably has an easement. The gas line interseciton coordinates with the property line should be noted. No perimeter fencing is noted on the drawing. An area/utility or/the access road should be analyzed. The sheet shows a less relinquish and/or access road on adjoining private property. Also, access road construction details should be given. The sheet shows two artesian water detention ponds. One indicates a dam height of approximately 20 to 25 feet and the other dam approximately 10 to 15 feet high. A rate water balance should be completed. Surface water runoff calculations and pond sizing should also be completed and presented for review.

3. Sheet 2. This sheet indicates shallow ground water interception and conveyance to private property west of the landfill area. Perimeter drainage will also be conveyed across private property to the west. Ground and surface water should be collected and routed to the west on adjacent property. No separate surface water detention is shown. The final contours proposed result in slopes of 4:1 percent for the existing landfill area. Erosion and slope stability analyses should be performed to determine the acceptability of these slopes. As the proposed ground water subdrain and gas line interaction, the contours indicate that the gas line is spanning the ditch. The contours should be revised. Similarly, the subdrain and gravel pit access road interaction contours should be changed. The current drawing assumes that the access road will be retained.

4. Sheet 3. This sheet shows the subdrain and gas line interaction to include a 100-foot corrugated metal pipe (CMP) and ditch to retain the gas line. The geotechnical construction of these soils may make this feasible. The gas line company probably has an agreement with water this plan must be consistent. The director, therefore, must have permission to construct as planned. The sheet indicates that the access road has been abandoned. This should be confirmed by those using the road. The subdrain will, as noted earlier, convey ground water (and surface water) to private property on the west. It is recommended that the subdrain grade be revised and all surface and ground water drainage be contained on district property. The subdrain, as designed, varies in elevation from 23,587 feet to 23,373 feet. Ground water below these elevations will continue to migrate north through the existing landfill. This ground water should be intercepted or intercepted mitigation provided below the existing landfill. Biopermeable liners for the subdrain should be included on this sheet. The subdrain excavation will be in water and trench stability issues should be addressed.

5. Sheet 4. The existing ground water level is reportedly at an elevation of 23,580 feet. The subdrain on Sheet 3 is at an elevation of 23,587 feet to 23,373 feet. The existing landfill contains trash below elevation 23,373 feet, which will continue to be saturated with the subdrain proposed. A method to provide continued saturation of the trash should be presented.

CONCLUSIONS:

The weak characterization of bedrock and shallow groundwater quality and flow, combined with the lack of a design for a leachate collection system, is a major concern. Placement of all downgradient and at least one upgradient monitoring wells within the required proximity of the waste area is a necessary addition to your plan.

The recommended method for diverting groundwater from the seeps away from the waste area, albeit cost effective, does not appear to be the most environmentally effective.

Your report represents a plan to substantially change your existing licensed landfill area by laterally expanding to the north. Substantial change to an existing facility may be subject to application review fees if Proposed Rule VIII, provided for by Section 75-10-115, MCA, is adopted. The application review fee under consideration by the Department, is currently $7,500.00 for an Intermediate Class Two Landfill. This proposed fee reflects the costs involved with the application review.

We realize that the process of improving the environment for your landfill operations has not been an easy one. The comments included in this document are meant to help, not criticize your efforts. We are here to help. If we can be of any assistance, please do not hesitate to call.

Sincerely,

Edward A. Thamke
Solid Waste Management

cc: Barry Damschen, P.E., Damschen & Associates, Inc., P.O. Box 4817, Helena, MT. 59604

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File: Hill County-Unified Disposal District, License #222

Page six

CONCLUSION

The user characteristics of hardcopy and medium retrieval/storage are very different, combined with the lack of a design for a inactive information system, it is my/an concern. Disadvantage of all approaches and as least one mechanism satisfying well within the requires operability of the basic area is a microfilm analyzer to your plan.

The recommendations concerning the diverting groundwater from the source away from the waste area, albeit not effective, does not appear to be the most cost-effectively effective.

Your report represents a plan to substantially change your existing landfill area by laterally expanding to the north. Substantial changes to an existing facility may be subject to application under the proposed New VIII/ provision for by Section 7A:10-113, NCA, is adopted. The application review the upper consideration by the Department, is currently, 1:1,000,000 for an interim class two landfill. This proposed due reflects the course involved with the application review.

We realize that the process of improving the environment for your landfill operations has not been an easy one. The comments included in this document are meant to help, not irritate your efforts. We are here to help. If we can be of any assistance, please do not hesitate to call.

Sincerely,

Edward A. Thomas
Solid Waste Management

cc: Barry Jones, Esq., P.E., Jackson & Associates, Inc., P.O. Box 8117, Malvern, PA 19355

s:/sln/solid/letter/swiss.ltr
File: Bill Swiss-Landfill Permit Objection, Linden 4222

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FAX (406) 449-8631

April 21, 1992

COPY

Mr. Edward A. Thamke
Department of Health and Environmental Sciences
Solid and Hazardous Waste Bureau
Cogswell Building
Helena, MT 59620

Dear Mr. Thamke:

This letter is a response to your review of the hydrogeological analysis for the existing sanitary landfill at Havre, Montana. In essence, this is a review of the proceedings of March 16, 1992, at which you, Jim Wilbur, Craig Stagner, Larry Broere, Clay Vincent, Bruce Siegmund and myself were in attendance.

1. Report Title. Since there has been no application made for an expansion area, the title reflects the hydrogeological characteristics of the existing landfill.

2. Table of Contents. The section in question should be deleted from the Table of Contents.

3. The requested information regarding climatic data appears on Table 1. The data show that Havre received five inches more precipitation than normal in 1989, following a year that experienced a net precipitation deficit of over six inches. The regional data, which include precipitation information from the northern high plains from Glacier National Park westward to Glasgow, shows a similar trend.

   Hershfield (1985) shows the 25-year, 24-hour rainfall event to be slightly less than three inches of precipitation.

4. Although not clearly indicated in the text, the elevations of stand pipes installed in the test pits were correlated to the top of the riser pipe.

5. As discussed at the meeting, test pits 5 and 16 did not contain water upon initial excavation. Water seeped into the pits over a period of time, and this was not properly reflected on Plate 2.

   As explained at the meeting, water from test pit #27 is, in fact, surface runoff from the landfill area, not ground water. This would explain the variation in total dissolved

Mr. Edward A. Thomas
Department of Health and Environmental Sciences
Solid and Hazardous Waste Bureau
Cogswell Building
Helena, MT 59620

Dear Mr. Thomas:

This letter is a response to your review of the hydrogeological analysis for the existing sanitary landfill at Havre. Pursuant to essence, this is a review of the proceedings of March 14, 1977, at which you, the writer, Craig Stephen, Larry Stevens, Clay Vincent, Bruce Sheppard and others were in attendance.

1. Report Title. Since there has been no application made for an expansion area, the title reflects the hydrogeological characteristics of the existing landfill.

2. Table of Contents. The section in question should be deleted from the Table of Contents.

3. The requested information regarding climatic data appears on Table 1. The data show that Havre received five inches more precipitation than normal in 1976, following a year that experienced a net precipitation deficit of over six inches. The regional data, which include precipitation information from the northern high plains from Glasgow westward to Glasgow, show a similar trend.

Beginning (1951) among the 25-year, 24-hour rainfall event to be slightly less than three inches of precipitation.

4. Although not clearly indicated in the text, the elevations of sump pipes installed in the test pits were correlated to the top of the riser pipe.

5. As discussed at the meeting, test pits 3 and 4 did not encounter water upon initial excavation. Water seeped into the pits over a period of time, and this was not properly recorded on Plate 2.

As explained at the meeting, water from near pit #23 is, in fact, surface runoff from the landfill area, not ground water. This would explain the variation in total dissolved

solids between samples from test pits 26 and 27.

The specific tests performed on each sample are clearly listed on Table 3. The sample obtained from test pit #5 was checked for temperature and specific conductivity, but was not submitted for further analysis. It is also noted on page 7 that only samples from test pits 16 and 27 were submitted for chemical analyses.

The complete analytical laboratory reports are included in Appendix I of the original report.

6. The sentence referred to in your response should have indicated that these samples were taken to determine the presence of any contaminants as well as to develop background values of ground-water chemistry. Since there was no detectable shallow ground water down-gradient of the landfill, it was impossible to obtain such a sample for analysis.

Many of the points brought up in your suggested plan shall be dealt with in an upcoming project designed to characterize the proposed expansion area north of the existing landfill. However, for the sake of clarity, it should be noted that point (1) has already been delineated on Plate 2. Drawing of flow lines parallel to the water table surface indicate an increased flow toward the gravel deposit, which is to be expected. Point (2) suggests the collection of additional samples from the shallow aquifer, which is wholly supported. The concept of collecting the samples "upgradient and downgradient of the bedrock aquifer" is not entirely clear, perhaps because the attitude of the bedrock aquifer is ambiguous. This leads to point (3), which involves the attitude of the potentiometric surface of the bedrock aquifer. The potentiometric surface appears to dip southward, away from the Milk River. This apparent inconsistency with the regional potentiometric surface can be explained by the fact that MW-1 was drilled closer to the discharge zone in the Milk River drainage. It may also be that the Milk River alluvial aquifer becomes a recharge zone during periods of low precipitation and may, in fact, bolster the ground water. In such a case, the potentiometric surface may dip to the south. In any case, the upcoming investigation of the proposed expansion area will, hopefully, resolve the issue. This study will also respond to points (4) and (5), which refer to additional ground water sampling and the relationship between the shallow and bedrock aquifers.

solids between samples from test pits 26 and 27.

The specific tests performed on each sample are clearly listed on Table 2. The sample obtained from test pit 27 was checked for temperature and specific conductivity, but was not submitted for further analysis. It is also noted on page 7 that only samples from test pits 16 and 27 were submitted for chemical analyses.

The complete analytical laboratory reports are included in Appendix I of the original report.

The reference referred to in your response should have indicated that these samples were taken to determine the presence of any contaminants as well as to develop background values of ground-water chemistry. Since there was no detectable shallow ground water down-gradient of the landfill, it was impossible to obtain such a sample for analysis.

Many of the points brought up in your suggested plan should be dealt with in an upcoming project designed to characterize the proposed expansion area north of the existing landfill. However, for the sake of clarity, it should be noted that point (1) has already been included on Plate 2. Drawing of flow lines parallel to the water table surface indicate an increased flow toward the gravel deposit. Which is to be expected. Point (2) suggests the collection of additional samples from the shallow aquifer, which is usually supported. The concept of collecting the samples "upgradient and downgradient of the bedrock aquifer" is not entirely clear, perhaps because the attitude of the bedrock aquifer is ambiguous. This leads to point (3), which involves the attitude of the potentiometric surface of the bedrock aquifer. The potentiometric surface appears to dip southward, away from the Milk River. This apparent inconsistency with the regional potentiometric surface can be explained by the fact that MW-1 was drilled closer to the discharge zone in the Milk River Coulee. It may also be that the Milk River alluvial aquifer becomes a recharge zone during periods of low precipitation and may, in fact, induce the ground water. In such a case, the potentiometric surface may dip to the south. In any case, the geometry (orientation) of the proposed expansion area will, hopefully, resolve the issue. This study will also respond to points (4) and (7), which refer to additional ground water sampling and the relationship between the shallow and bedrock aquifers.

7 through 13.

These items will be addressed, where appropriate, in the upcoming investigation of the proposed lateral expansion area. This was generally agreed to by all in attendance on the basis that the deep ground water was not the subject of immediate concern; rather, the excavation of the drainage ditch was paramount in order to immediately eliminate the possibility of water entering the landfill.

Comments regarding the drawings were discussed, and numerous changes were explained. Items such as the natural gas line easement, draining of storm water onto private property, erosion and slope stability were explained. It was agreed that a new plan sheet of the proposed drainage excavation would be drafted, and copies of those have since been submitted to the Department.

Several other points were discussed. It was pointed out that new fences have been erected on the eastern end of the landfill. It was also noted that the drainage ditch will drain toward the west, emptying into a pond within the site boundaries. The location of one additional monitoring well was proposed in the northeastern portion of the landfill, within the prescribed 150 meters of the waste pit. Finally, ideas were exchanged for the construction of a leachate detection and collection system at the western end of the existing landfill.

If you have any additions or corrections to this record of proceedings, please contact us.

Yours very truly,

DAMSCHEN & ASSOCIATES, INC.

Barry E. Damschen, P.E.
Project Manager

BED/BS/jmr
Enclosure
cc: Clay Vincent, Hill County Sanitarian/Planner

Table 1. Precipitation data for Havre, Montana and the north-central Great Plains of Montana.

Station	Average Annual Precip. (inches)	Annual Precip. 1988 (inches)	Annual Precip. 1989 (inches)
Havre Airport	11.18	6.38	16.18
North-central region	13.09	10.00	19.23

TRANSMISSIVITIES

WALTON (1987) p. 19

$Q/s = T/2000$

Q = DISCHARGE gpm
S = DRAWDOWN ft
Q/s = SPECIFIC CAPACITY WITH FULL PENETRATION gpm/ft
T = TRANSMISSIVITY gpd/ft

$T = Q/s\ 2000$

MW-1	MW-2	SHOP WELL	1/2 MI. NO.
Q = 10 gpm	Q = 3 gpm	Q = 2 gpm	Q = 20 gpm
S = 101 ft	S = 37 ft	S = 40 ft	S = 31 ft
Q/s = 0.10 gpm/ft	Q/s = 0.08 gpm/ft	Q/s = 0.05 gpm/ft	Q/s = 0.6 gpm/ft
T = 200 gpd/ft	T = 160 gpd/ft	T = 100 gpd/ft	T = 1300 gpd/ft

HYDRAULIC CONDUCTIVITY

U.S. BUREAU of RECLAMATION, 1981 p. 28

$T = KM$

T = TRANSMISSIVITY (gpd/ft)
K = PERMEABILITY (HYDR. COND) (gpd)
M = AQUIFER THICKNESS (ft)

$K = T/M$

MW-1
T = 200 gpd/ft
M = 12 ft
K = 16.7 gpd/ft² ✓ WALTON 1989 P. 139
= 16.7×10^{-4} ft/min
9×10^{-4} cm/s

MW-2
T = 160
M = 5
K = 32 ✓
= 32×10^{-4} ft/min
= 1.51×10^{-3} cm/s

SHOP
T = 100
M = 10
K = 10 ✓
= 10×10^{-4} ft/min
= 4.7×10^{-4} cm/s

1/2 mi. north
T = 1300
M = 20
K = 65 ✓
= 65×10^{-4} ft/min
= 3.1×10^{-3} cm/s

VELOCITY OF AQUIFER - BASED ON DARCY'S LAW

$$V = \frac{K}{n}\frac{dh}{dl}$$

V = TRACER VELOCITY

K = HYDRAULIC CONDUCTIVITY

n = POROSITY (IN SAND - EFFECTIVE POROSITY IS NEAR TOTAL

n_e = EFFECTIVE POROSITY = SPECIFIC YIELD

$\frac{dh}{dl}$ = GRADIENT

K = BETWEEN MW-1 AND MW-2 = $\frac{880+1700}{2}$ = 1290 FT/YR

n = .25 TO .50 (WALTON, 1993)

n_e = .10 TO .40

USE → .25

dh = 8 FT

dl = 2750 FT

$\frac{dh}{dl}$ = 0.0029

$$V = \frac{1290 \text{ ft/yr}}{0.25} \; 0.0029$$

V = 15 FT/YR BETWEEN MW-1 AND MW-2

Table 3.4 USC System Chart

Major Divisions			Group Symbols	Typical Names
Coarse-Grained Soils More than 50% retained on No. 200 sieve*	Gravels 50% or more of coarse fraction retained on No. 4 sieve	Clean Gravels	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		Gravels With Fines	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	Sands More than 50% of coarse fraction passes No. 4 sieve	Clean Sands	SW	Well-graded sands and gravelly sands, little or no fines
			SP	Poorly graded sands and gravelly sands, little or no fines
		Sands With Fines	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
Fine-Grained Soils 50% or more passes No. 200 sieve*	Silts and Clays Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	Silts and Clays Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity
Highly Organic Soils			PT	Peat, muck and other highly organic soils

*Based on the material passing the 3-in. (75-mm) sieve.

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SAMPLE #	DESCRIPTION
15	SHALE, DARK REDDISH BROWN, VERY SOFT, MODERATELY SEVERELY WEATHERED, MOIST, FISSILE TO BLOCKY, THIN COAL SEAMS, FOSSILIFEROUS
A	
B	SHALE, DARK GRAY, SOFT TO VERY SOFT, SLIGHTLY WEATHERED, MOIST, FISSILE TO LAMINATED, LIMONITE STAINS ON JOINTS
C	LEAN TO FAT CLAY (CL/CH), TAN TO BROWN, MOTTLED, MEDIUM TO HIGH PLASTICITY, FIRM TO STIFF, SILTY, MOIST, ROOTS, BLOCKY
#2	SILTSTONE, REDDISH ORANGE, MODERATELY HARD, SLIGHTLY TO MODERATELY WEATHERED, LIMONITE AND PYROLUSITE STAINS ON JOINTS, TRACE LEAF FOSSILS
	SANDY SILTSTONE, LIGHT GRAY, MODERATELY HARD, VERY SLIGHTLY WEATHERED LAMINATED, BLOCKY, SLIGHTLY FOSSILIFEROUS, TRACE
	CLAYSTONE, OLIVE, SOME SILT, VERY SOFT, SEVERELY WEATHERED TRACE BITUMEN, FRACTURED, MEDIUM PLASTICITY, MOIST
	CLAYEY SILTSTONE, BROWN, VERY SOFT, VERY SEVERELY WEATHERED, MOIST, MEDIUM PLASTICITY, TR. LIMONITE, TR. GYPSUM, TR. BITUMEN, FISSILE

#29 SHALE, DARK GRAY, MODERATELY HARD, FRESH, TR. FOSSILS
(A) SILTY

(B) SANDSTONE, LIGHT BROWNISH GRAY, FINE GRAINED, MODERATELY WELL SORTED, SUBANGULAR TO SUBROUNDED, MOSTLY QUARTZ, PERMEABLE, SOFT, MODERATE TO SLIGHTLY WEATHERED, BLOCKY, TR. FOSSILS, MOIST

(C) THINLY INTERBEDDED: SANDSTONE, VERY DARK BROWN, SILTY, VERY FINE GRAINED WITH SANDSTONE, AS ABOVE INTERBEDS THIN AND DISCONTINUOUS

(D) INTERBEDDED: SHALE, LIGHT OLIVE, MEDIUM HARDNESS, SLIGHTLY WEATHERED, LAMINAE OF BITUMEN; AND SANDSTONE, FINE TO VERY FINE GRAINED, MODERATELY SORTED, SILTY, LAMINAE OF BITUMEN SLIGHTLY PERMEABLE LIMONITE STAINING ON JOINTS

(E) FAT CLAY (CH), LIGHT YELLOWISH OLIVE, HIGH PLASTICITY, SOFT, MOIST LIMONITE STAINING, WET, TRACE CRYSTALLINE GYPSUM

(F) SANDSTONE, VERY DARK BROWN, VERY FINE GRAINED, MEDIUM HARD, SLIGHTLY WEATH. SILTY

22 SILTY SAND (SM) BROWN, VERY FINE TO COARSE GRAINS, ~~VERY~~ WELL GRADED, SHALE AND SANDSTONE FLOATERS UP TO 1" MODERATELY DENSE, MOIST.

#30 SANDY SILT (ML) LIGHT BROWN TO BROWN, LOW PLASTICITY, STIFF TO VERY STIFF, MOIST, ROOTS, GYPSUM VEINLETS

#7 SILTY SANDSTONE, BLACK, FINEGRAINED BITUMINOUS, HARD, FRESH, LOW POROSITY

A BLOCKY, PIECES AND LAMINAE OF BITUMEN

B SANDSTONE, GRAY, FINE GRAINED, WELL SORTED, MODERATELY CEMENTED, CARBONATE CEMENT, MASSIVE, PERMEABLE

#14 CLAY SHALE, OLIVE GRAY, SOFT, SLIGHTLY WEATHERED TO FRESH

A MOIST, TR. FOSSILS

B COAL, BLACK, THIN BEDDED, 80-90% PURE, SOFT

C SILTY SAND (SM), BROWN TO LIGHT BROWN FINE GRAINED, WELL GRADED, COAL ~~[illegible]~~, SILTSTONE AND AGATE FLOATERS UP TO 1/4, POCKETS LIMONITE, MEDIUM DENSE TO DENSE, MOIST

D LEAN CLAY (CL), VERY DARK BROWN, SILTY, LOW PLASTICITY, FIRM, MOIST, POCKETS FINE TO MEDIUM GRAINED SAND, FLOATERS OF OLIVE CLAYSTONE, TR. BITUMEN, TR. GYPSUM

MW

#20 SANDY SILT (ML), LIGHT YELLOWISH BROWN, LOW PLASTICITY, FINE TO VERY FINE GRAINED SAND, VERY STIFF, MOIST, FRAGMENTS OF

A QUARTZITE AND GNEISS UP TO 1" POCKETS OF LIMONITE.

B FAT CLAY (CH), BLACK TO VERY DARK BROWN, HIGH PLASTICITY, DAMP TO MOIST, ROOTS.

#11 SILT (ML), LIGHT GRAYISH BROWN, LOW PLASTICITY, SOFT, DRY TO DAMP

A ROOTS

B SHALE, VERY DARK BROWN, SOFT TO MEDIUM HARD, FRESH TO VERY SLIGHTLY WEATHERED, TR. BITUMEN, CALCITE ON JOINTS, SLIGHTLY FISSILE

C SANDSTONE, LIGHT GRAY, FINE GRAINED, MODERATELY WELL SORTED, MEDIUM HARD, MODERATELY WEATHERED, UNCEMENTED, PERMEABLE FLOATERS OF GRAY SHALE UP TO 2"

D SANDSTONE, ORANGE-BROWN, VERY FINE TO FINE GRAINED, MOD. WEL SORTED. POORLY CEMENTED, LIMONITE CEMENT, HARD TO MODERATEL HARD, MODERATELY WEATHERED, SLIGHTLY PERMEABLE,

#27 A SILTY SAND (SM), LIGHT GRAYISH BROWN, FINE GRAINED SAND, LOOSE TO MEDIUM DENSE, POORLY GRADED, MOIST, GYPSUM STRINGERS

B CLAYEY SAND (SC), BROWNISH GRAY, VERY FINE GRAINED, POORLY GRADED, LOOSE TO MEDIUM DENSE, MOIST, TR. GYPSUM, TR. FINE TO MEDIUM GRAINED SAND

#28 A FAT SILTY CLAY (CH/MH) OLIVE BROWN, HIGH PLASTICITY, SOFT, MOIST, ROOTS, TR. BITUMEN

B FAT CLAY (CH) BROWN, HIGH PLASTICITY, FIRM, MOIST, ROOTS

C SHALE, GRAYISH BROWN, MEDIUM HARD, ~~FRESH~~ ~~HARD~~ TO SLIGHTLY WEATHERED, LIMONITE AND PYROLUSITE ON JOINTS

D SILTSTONE, OLIVE GRAY, MEDIUM HARD TO HARD, SLIGHTLY WEATHERED, LIMONITE STAINING ON JOINTS, TR. V. FINE SAND

E SILTSTONE, DARK BLUE GRAY TO OLIVE, HARD TO MEDIUM HARD, SLIGHTLY WEATHERED, LIMONITE STAINING ON JOINTS

F SILTY SAND (SM), ORANGE BROWN, FINE TO V. FINE GRAINED, WELL GRADED, ABUNDANT LIMONITE, TR. BITUMEN, LOOSE TO MODERATELY DENSE, MOIST

#12 FOSSIL ~~[illegible]~~ CONGLOMERATE, MIXED BLACK AND ORANGE SHELLS AND BITUMEN CLASTS.

A LIMONITE MATRIX, SOFT TO MODERATELY HARD.

B SILTY CLAYSTONE, OLIVE GRAY, MEDIUM HARD, SLIGHTLY WEATHERED, LIMONITE AND PYROLUSITE ON JOINTS, FR. FOSSILS

#4 SILTY SAND (SM), BROWN, VERY FINE GRAINED, POORLY GRADED, NON PLASTIC, DENSE, LIMONITE STAINING ON JOINTS

LEAN CLAY (CL), BROWN, SILTY, SANDY, LOW PLASTICITY, SOME GRAVEL, STIFF, MOIST

SILT CALICHE, WHITE, LOW PLASTICITY, GYPSUM, COLLAPSIBLE, DAMP, ~~[illegible]~~

SILTSTONE, ORANGE, VERY HARD, ABUNDANT LIMONITE IN LIESEGANG BANDING, LIMONITE AND PYROLUSITE ON JOINTS, DRY TO DAMP

#17 SANDSTONE, OLIVE GRAY, VERY FINE GRAINED, VERY WELL SORTED,

A PERMEABLE, POORLY TO UNCEMENTED, LIMONITE ON JOINTS

B SILTSTONE, ORANGE-BROWN, MODERATELY HARD, ABUNDANT LIMONITE, ~~MODERATELY WEATHERED~~ CALCITE AND PYROLUSITE ON JOINTS

#6 SILTY CLAYSTONE, DARK BLUE-GRAY, SOFT TO MEDIUM HARD, VERY

A SLIGHTLY WEATHERED, BLOCKY, LIMONITE ON JOINTS

B CLAYSTONE, BLACK, SOFT TO MEDIUM HARD, VERY SLIGHTLY WEATHERED, SLIGHTLY FRACTURED, BITUMENOUS

C SILTY CLAYSTONE, OLIVE, SOFT TO MEDIUM HARD SLIGHTLY WEATHERED, MODERATELY FRACTURED, TR. FOSSILS, PYROLUSITE ON JOINTS

D SILTY CLAY (CL/ML), REDDISH BROWN, LOW PLASTICITY, FIRM, ABUNDANT PIECES OF WEATHERED SILTY CLAYSTONE, DARK BLUEISH GRAY

#23 SILT CALICHE, MOTTLED WHITE AND LIGHT GRAYISH BROWN, ~~COLOR~~

A WEAKLY CEMENTED, DRY, FIRM

SANDY SILTSTONE ~~(ML)~~, GRAYISH BROWN, V. FINE GRAINED SAND, ~~VERY STIFF~~

B SOFT, MODERATELY SEVERELY WEATHERED, POCKETS LIMONITE, PYROLUSITE ON JOINTS, POCKETS SAND, FINE GRAINED

C SILTY SAND (SM), BROWN, FINE TO VERY FINE GRAINED, TR. LIMONITE AND PYROLUSITE, POCKETS WEATHERED SANDSTONE

#19 SILTY ~~SANDSTONE~~ (SM), LIGHT GRAYISH BROWN, ~~SOFT~~ MODERATELY DENSE, ~~MODERATELY SEVERELY~~

(A) ~~WEATHERED~~, POORLY CEMENTED, VERY FINE GRAINED, TR PYROLUSITE, GRADES TO SANDY SILTSTONE, DENSE

#3 SANDY SILT TO LEAN CLAY (ML/CL), DARK BROWN TO LIGHT BROWN
LOW PLASTICITY, VERY FINE GRAINED, STIFF, TR GRAVEL

#5 SILTY CLAYSTONE, GRAY, SOFT, MODERATELY WEATHERED, SEVERELY
A JOINTED, LIMONITE ON JOINTS AND UP TO 1/4 INCH INTO ROCK

B SILTY CLAYSTONE, DARK GRAYISH BROWN, VERY SOFT, SEVERELY WEATHERED,
LIMONITE AND PYROLUSITE ON ABUNDANT JOINTS

CLAYSTONE, GRAYISH BROWN, SOFT, SLIGHTLY WEATHERED, BLOCKY
C TR LIMONITE AND PYROLUSITE ON JOINTS

CLAYSTONE, VERY DARK GRAYISH BROWN, SOFT MODERATELY WEATHERED
D HIGH PLASTICITY, THIN TO MEDIUM BEDDED LIMONITE ON JOINTS,
INTERBEDDED WITH: SILTSTONE, VERY DARK BROWN, ABUNDANT BITUMEN,
SOME LIMONITE, SOFT TO VERY SOFT

E SILTSTONE, DARK GRAYISH BROWN, VERY SOFT, MODERATELY SEVERELY WEATHERED,
~~[illegible]~~ SEVERELY JOINTED, LIMONITE ON JOINTS

FAT CLAY (CH), GRAYISH BROWN, HIGH PLASTICITY, SILTY, VERY STIFF;
F AND CLAYEY SAND (SC), LIGHT BROWN, VERY FINE GRAINED, POORLY
GRADED, DENSE; AND POCKETS BITUMEN

#3 SHALE, GRAY ASWHOLE, LAMINATED VERY LIGHT GRAY AND OLIVE, MOSTLY

A SILT, MODERATELY HARD, SLIGHTLY WEATHERED, TR. LIMONITE, TR FOSSILS

B SHALE, DARK OLIVE, MOSTLY CLAY, MODERATELY HARD, SLIGHTLY WEATHERED TR LIMONITE AND PYROLUSITE ON JOINTS

C SHALE, VERY DARK BROWN TO BLACK MODERATELY HARD, SLIGHTLY WEATHERED, ABUNDANT BITUMEN THROUGHOUT AND IN POCKETS, LIMONITE ON JOINTS

D SHALE, OLIVE TO BLACK, VERY SOFT, SEVERELY WEATHERED, SEVERELY JOINTED, TR LIMONITE AND PYROLUSITE ON JOINTS

E CLAYSTONE, BROWNISH YELLOW, SOFT, MODERATELY WEATHERED, LAMINAE OF BITUMEN

F SILTY CLAY (CL/ML), DARK BROWN, LOW PLASTICITY FIRM, JOINTED POCKETS OLIVE YELLOW CLAYSTONE, POCKETS BITUMEN

G ~~CLAYSTONE~~ SHALE, BROWNISH YELLOW MODERATELY HARD, SLIGHTLY WEATHERED FISSILE TO SHALEY, MOSTLY CLAY, LIMONITE AND TR PYROLUSITE ON JOINTS

H SILTSTONE, LIGHT REDDISH BROWN WITH POCKETS OF GRAY, VERY HARD, MODERATELY WEATHERED. LIMONITE THROUGHT EXCEPT GRAY POCKETS, BLOCKY LIMONITE AND DENDRITIC PYROLUSITE ON JOINTS.

#25 SANDSTONE, GRAY, FINE GRAINED, WEAKLY CEMENTED MODERATELY HARD TO SOFT,

A MODERATELY WEATHERED, TR. LAMINAE OF SILTSTONE, TR. PYROLUSITE ON BEDDING

B SANDSTONE, LIGHT GRAYISH OLIVE, FINE GRAINED, UNCEMENTED, VERY SOFT, MODERATELY SEVERELY WEATHERED, POCKETS LIMONITE, TR. FOSSILS

C SILTY CLAY (CL/ML), DARK BROWN, LOW PLASTICITY, FIRM, TR. GRAVEL, POCKETS LIMONITE AND GYPSUM

D SILTSTONE, GRAYISH RED, VERY HARD, FRESH, TR. PYROLUSITE ON JOINTS

#16 SILTSTONE, DARK OLIVE, CLAYEY, MODERATELY HARD, SLIGHTLY WEATHERED

A LIMONITE AND PYROLUSITE ON JOINTS

B CLAYSTONE, BROWNISH OLIVE, VERY SOFT, VERY SEVERELY WEATHERED POCKETS BITUMEN, LIMONITE THROUGHOUT

C CLAYSTONE, BROWN, SOFT, MODERATELY WEATHERED, STRINGERS OF BITUMEN AND GYPSUM

D CLAYSTONE, LIGHT OLIVE, VERY SOFT, SEVERELY WEATHERED, TR LIMONITE, TR BITUMEN IN POCKETS, ROOTS

#2 A SILTY CLAY (CL/ML), ~~DARK BROWN~~, LOW PLASTICITY, FIRM, TR. ROUNDED GRAVEL, POCKETS GYPSUM

B SILT (ML), VERY LIGHT BROWN, FIRM, CEMENTED, COLLAPSIBLE, DRY, LOW TO NO PLASTICITY

#3 POORLY GRADED SAND (SP), BROWN, VERY FINE TO FINE GRADED, POORLY GRADED, LOOSE, LAYERED, SILTY IN LAYERS, ERRATICS OF VERY HARD METAMORPHIC ROCK UP TO 4" AVERAGE DIAMETER.

#9 A SILTSTONE, LIGHT OLIVE GRAY, HARD TO MODERATELY HARD, SLIGHTLY WEATHERED, SHALEY IN PLACES, LIMONITE ON JOINTS, TR. WORM BURROWS.

B SHALE, OLIVE TO DARK OLIVE, HARD TO MODERATELY HARD, SLIGHTLY WEATHERED, LIMONITE ON JOINTS, TR. WORM BURROWS

C LEAN CLAY (CL), DARK BROWN, SILTY, STIFF TO VERY STIFF, LOW PLASTICITY, TR. POCKETS BITUMEN, TR. LIMONITE AND GYPSUM

LOG OF TEST PITS

TP-1

0-4.6'	BLACK CLAY
4.6'-7'	MED. CLAY
7'-9'	GRAY CLAY
9'-11'	FRACTURED
11'-12.7'	RED - clay
12.7'-15'	LIGHT - clay
15'-17.6'	COAL

17.6' = TOTAL DEPTH

WATER ENCOUNTERED AT 15'

TP-2

0-2.5'	TOPSOIL
2.5'-5'	GRAVELLY CLAY
5'-7'	GRAVEL
7'-10'	CLAYSTONE, OLIVE
10'-11'	SILTSTONE, REDDISH, ORANGE
11'-12'	COAL
12'-13.5'	CLAYEY SILTSTONE, BROWN
13.5'-16'	SANDY SILTSTONE, LIGHT GRAY
16'-19.5'	TAN MIXTURE

19.5' = TOTAL DEPTH

WATER ENCOUNTERED AT 11.5'

TP-3

0-2'	TOPSOIL
2'-6'	LOESS/SAND
6'-11.7'	POORLY GRADED SAND (SP), BROWN
11.7'-12.5'	CLAY
12.5'-19.5'	SAND & GRAVEL

19.5' = TOTAL DEPTH

WATER ENCOUNTERED AT 12.5'

LOG OF TEST PITS

TP-1

0-4.0'	BLACK CLAY
4.0'-7'	RED, CLAY
7'-9'	GRAY CLAY
9'-11'	FRACTURED
11'-12.7'	RED
12.7'-15'	LIGHT GRAY
15'-17.0'	COAL

17.0' = TOTAL DEPTH

WATER ENCOUNTERED AT 15'

TP-2

0-3.5'	TOPSOIL
3.5'-6'	GRAVELLY CLAY
6'-7'	GRAVEL
7'-10'	GRAYSTONE, OLIVE
10'-11'	SILTSTONE, MAROON, ORANGE
11'-12'	COAL
12'-12.5'	CHERTY SILTSTONE, BROWN
12.5'-16'	SANDY SILTSTONE, LIGHT GRAY
16'-19.5'	TAN MUDSTONE

19.5' = TOTAL DEPTH

WATER ENCOUNTERED AT 11.5'

TP-3

0-2'	TOPSOIL
2'-6'	LOAMS/SAND
6'-12.7'	MODERT BROWN SAND (MP), BROWN
12.7'-12.5'	GRAY
12.5'-19.5'	RED & GRAYSH

19.5' = TOTAL DEPTH

WATER ENCOUNTERED AT 12.5'

TP-4

0-2.5'	SILT CALICHE, WHITE
2.5'-5.5'	LEAN CLAY (CL), BROWN
5.5'-7.3'	SILTY SAND (SM), BROWN
7.3'-10'	SILTSTONE, ORANGE
10-'12.5'	SAND & CLAY
12.5'-19'	CLAY

19' = TOTAL DEPTH

WATER ENCOUNTERED AT 13.5'

TP-5

0-3'	GRAVEL
3'-12'	FAT CLAY (CH), GRAYISH BROWN
12'-16.5'	SILTSTONE & CLAYSTONE, DARK GRAYISH BROWN TO VERY DARK GRAYISH BROWN (B+D+E)
16.5'-19'	CLAYSTONE TO SILTY CLAYSTONE, GRAY TO GRAYISH BROWN (A+C)

19' = TOTAL DEPTH

NO WATER INDICATED

TP-6

0-3'	SILTY CLAY (CL/ML) REDDISH BROWN (D)
3'-5'	CLAYISH GRAVEL
5'-9'	GRAVEL
9'-14.5'	SILTY CLAYSTONE, OLIVE (C)
14.5'-18.5'	CLAYSTONE, BLACK (B)
18.5'-19.5'	SILTY CLAYSTONE, DARK BLUISH GRAY (A)

19.5' = TOTAL DEPTH

WATER ENCOUNTERED AT 9'

TP-4

0-2.5'	SILT CAICIUMS, WHITE
2.5'-5.5'	LEAN CLAY (CL), BROWN
5.5'-7.5'	SILTY SAND (SM), BROWN
7.5'-10'	SILTSTONE, GRAYSH
10-'12.5'	SAND & CLAY
12.5'-15'	CLAY

15' = TOTAL DEPTH

WATER ENCOUNTERED AT 12.5'

TP-5

0-2'	GRAVEL
2'-12'	FAT CLAY (CH), GRAYISH BROWN
12'-16.5'	SILTSTONE & CLAYSTONE, DARK GRAYISH BROWN TO VERY DARK GRAYISH BROWN (B+D+E)
16.5'-18'	CLAYSTONE TO SILTY CLAYSTONE, GRAY TO GRAYISH BROWN (A+C)

18' = TOTAL DEPTH

NO WATER INDICATED

TP-6

0-1'	SILTY CLAY (CL/ML) MEDDIUM BROWN (D)
1'-2'	CLAYISH GRAVEL
2'-5'	GRAVEL
5'-16.5'	SILTY CLAYSTONE, OLIVE (C)
16.5'-18.5'	CLAYSTONE, BLACK (B)
18.5'-19.5'	SILTY CLAYSTONE, DARK BROWN GRAY (A)

19.5' = TOTAL DEPTH

WATER ENCOUNTERED AT 9'

TP-7

0'-5'	GRAVEL
5'-7.8'	GRAVELLY, RUBBLY CLAY
7.8'-12.5'	BLUE SHALE
12.5'-13'	SILTY SANDSTONE, BLACK (A)

13' = TOTAL DEPTH

WATER ENCOUNTERED AT 7.8'

TP-8

0'-2'	TOPSOIL
2'-3.7'	GRAVEL
3.7'-6.8'	SILTY CLAY (CL/ML) DARK BROWN (F)
6.8'-7.5'	CLAYSTONE, BROWNISH YELLOW (E)
7.5'-9'	SHALE, VERY DARK BROWN TO BLACK (C)
9'-13.7'	SHALE, OLIVE TO BLACK TO BROWNISH YELLOW (B+D+G)
13.7'-15.8'	SHALE, GRAY (A)
15.8'-18.7'	SILTSTONE, LIGHT REDDISH BROWN (H)

18.7' = TOTAL DEPTH

WATER ENCOUNTERED AT 6.8'

TP-9

0-1.5'	LEAN CLAY (CL), DARK BROWN (C)
1.5'-4'	SAND
4'-5'	GRAVEL LENSE
5'-6'	SAND
6'-8.7'	SHALE, OLIVE TO DARK OLIVE (B)
8.7'-18'	SILTSTONE, LIGHT OLIVE GRAY, (A)

18' = TOTAL DEPTH

NO WATER INDICATED

TP-7

0'-5'	GRAVEL
5'-7.5'	GRAVELLY, MEDIUM CLAY
7.5'-12.5'	BLUE SHALE
12.5'-13'	SILTY SANDSTONE, BLACK (A)

13' = TOTAL DEPTH

WATER ENCOUNTERED AT 7.5'

TP-8

0'-2'	TOPSOIL
2'-3.7'	GRAVEL
3.7'-6.5'	SILTY CLAY (CL/ML) DARK BROWN (E)
6.5'-7.5'	CLAYSTONE, WEATHERED YELLOW (E)
7.5'-9'	SHALE, VERY DARK BROWN TO BLACK (C)
9'-13.7'	SHALE, OLIVE TO BLACK TO ETCHWALLEN YELLOW (E-B-D)
13.7'-15.5'	SHALE, GRAY (A)
15.5'-18.7'	SILTSTONE, LIGHT MAGOLEN BROWN (M)

18.7' = TOTAL DEPTH

WATER ENCOUNTERED AT 6.5'

TP-9

0-1.5'	LEAN CLAY (CL), DARK BROWN (E)
1.5'-4'	SAND
4'-5'	GRAVEL LENSE
5'-6'	SAND
6'-8.7'	SHALE, DARK TO DARK OLIVE (E)
8.7'-14'	SILTSTONE, LIGHT OLIVE GRAY (A)

14' = TOTAL DEPTH

NO WATER ENCOUNTERED

TP-10

0.-2.6'	TOPSOIL
2.6'-5.1'	LOESS CLAY
5.1'-7.9'	GRAVEL
7.9'-9.7'	GRAY CLAY
9.7'-11.5'	REDROCK CLAY
11.5'-14'	GRAY-TAN CLAY
14'-15'	COAL
15'-20'	ORGANIC CLAY THIN TAN HEAVY CLAY

20' = TOTAL DEPTH

WATER ENCOUNTERED AT 5.1'

TP-11

0-1'	TOPSOIL
1'-3'	SILT (ML), LIGHT GRAYISH BROWN, (A)
3'-9.2'	SANDSTONE, LIGHT GRAY (C)
9.2'-10.3'	GRAY CLAY
10.3'-12'	SANDSTONE, ORANGE-BROWN (D)
12'-19'	SHALE, VERY DARK BROWN (B)

19'= TOTAL DEPTH

NO WATER INDICATED

TP-12

0-1.5'	TOPSOIL
1.5'-4.5'	LOESS SILT
4.5'-9'	SANDY GRAVEL - SOME SILT
9'-11'	CLAY, SHELLS
11'-13'	FOSSIL CONGLOMERATE (A)
13'-16.5'	SILTY CLAYSTONE, OLIVE GRAY (B)

16.5-17.5 = TOTAL DEPTH

NO WATER INDICATED

TP-13

0-1.5'	TOPSOIL
1.5'-3.5'	BLACK
3.5'-5.5'	DARK BROWN
5.5'-7.5'	LIGHT FRACTURED CLAY
7.5'-14.5'	HARDER REDDISH CLAY
14.5'-18'	LIGHTER CLAY, SOME RED

18' = TOTAL DEPTH

NO WATER INDICATED

TP-14

0-2'	TOPSOIL
2'-3'	WHITE
3'-6.5'	SILTY SAND, BROWN TO LT. BROWN (C)
6.5'-10'	RED ORGANIC CLAY W/SOME COAL
10'-11.5'	COAL, BLACK (B)
11.5'-13'	LIGHTER CLAY
13'-16.5'	LEAN CLAY (CL), VERY DARK BROWN
16.5'-19'	CLAY SHALE, OLIVE GRAY (A)

19' = TOTAL DEPTH

WATER ENCOUNTERED AT 10' & 13'

TP-15

0-2.5'	TOPSOIL
2.5'-4.5'	WHITE ORGANIC
4.5'-5.5'	BLACK COAL
5.5'-8'	RED ROCK
8'-13'	LEAN TO FAT CLAY (CL/ML), (C)
13'-14'	RED ROCK WITH COAL
14'-18'	SHALE, DARK REDDISH BROWN, (A)

18' = TOTAL DEPTH

NO WATER INDICATED

TR-12

0-2.5'	TOPSOIL
2.5'-5.5'	CLAY
5.5'-5.5'	DARK BROWN
5.5'-7.5'	LIGHT FRACTURED CLAY
7.5'-14.5'	DARKER REDDISH CLAY
14.5'-15'	WEATHER CLAY, SOME RED

15' = TOTAL DEPTH

NO WATER INDICATED

TR-13

0-2	TOPSOIL
2'-3	WHITE
3'-6.5'	SILTY SAND, BROWN TO LT. BROWN (C)
6.5'-16'	DAR CARBONIC CLAY W/SOME COAL
16'-17.5'	COAL, BLACK (S)
17.5'-18'	LIGHTER CLAY
18'-18.5'	DARK CLAY (CL), VERY CLOSE BROWN
18.5'-19'	CLAY SHALE, OLIVE GRAY (A)

20' = TOTAL DEPTH

WATER RECOVERED AT 16' & 18'

TR-14

0-2.5'	TOPSOIL
2.5'-4.5'	WHITE ORGANIC
4.5'-5.5'	BLACK COAL
5.5'-8'	RED ROCK
8'-13'	LARGE TO TAN CLAY (CL/ML), (O)
13'-14'	RED ROCK WITH COAL
14'-18'	SHALE, DARK WEATHER BROWN, (A)

18' = TOTAL DEPTH

NO WATER INDICATED

TP-16

0-0.5'	TOPSOIL
0.5'-5'	CLAYSTONE, LIGHT OLIVE (D)
5'-7.5'	CLAYSTONE, BROWN (C)
7.5'-9.6'	CLAYSTONE, BROWNISH OLIVE (B)
9.6'-17'	CLAYEY SILTSTONE, DARK OLIVE (A)

17' = TOTAL DEPTH

NO WATER INDICATED

TP-17

0-1.5'	TOPSOIL
1.5'-7'	MEDIUM CLAY
7'-10'	SILTSTONE, ORANGE BROWN (B)
10'-18'	SANDSTONE, OLIVE GRAY (A)

18' = TOTAL DEPTH

WATER ENCOUNTERED AT 7'

TP-18

0-2'	TOPSOIL
2'-21'	CLAY, SANDY

21' = TOTAL DEPTH

NO WATER INDICATED

TP-19

0-2'	TOPSOIL
2'-4'	SILTY SAND (SM), LIGHT GRAYISH BROWN (A)
4'-19'	SANDY SILT TO LEAN CLAY (ML/CL) (B)

19' = TOTAL DEPTH

NO WATER INDICATED

TP-20

0-3'	TOPSOIL
3'-6'	FAT CLAY (CH), (B)
6'-18.5'	SANDY SILT (ML), (A)

18.5' = TOTAL DEPTH

NO WATER INDICATED

TP-21

0-2'	TOPSOIL
2'-4.5'	SILT (ML), VERY LIGHT BROWN (B)
4.5'-5.5'	SAND
5.5'-18'	SILTY CLAY (CL/ML), (A)

18' = TOTAL DEPTH

NO WATER INDICATED

TP-22

0'-2.5'	TOPSOIL
2.5'-4.5'	LOAM CLAY
4.5'-19'	SILTY SAND (SM)

19' = TOTAL DEPTH

NO WATER INDICATED

TP-23

0-2'	TOPSOIL
2'-3.5'	GRAVEL-DRY
3.5'-4.5'	SILT CALICHE (A)
4.5'-6'	DARK CLAY
6'-8'	SILTY SAND (SM) (C)
8'-20'	SANDY SILTSTONE (B)

20' = TOTAL DEPTH

NO WATER INDICATED

TP-24

0-2'	TOPSOIL
2'-4'	WHITE clay
4'-9'	CLAY
9'-11.5'	SANDY CLAY
11.5'-18'	CLAY

18' = TOTAL DEPTH

NO WATER INDICATED

TP-25

0-1.5'	TOPSOIL
1.5'-3.5'	SILTY CLAY (CL/ML) (C)
3.5'-6.5'	SILTSTONE, GRAYISH RED (D)
6.5'-7.5'	SANDSTONE, GRAY (A)
7.5'-18.5'	SANDSTONE (B)

18.5' = TOTAL DEPTH

NO WATER INDICATED

TP-26

0-2.5'	TOPSOIL
2.5'-5'	BLACK CLAY
5'-7'	WHITE SOIL
7'-9'	ROCKY CLAY
9'-19'	CLAY

19' = TOTAL DEPTH

NO WATER INDICATED

TP-27

0-3'	TOPSOIL
3'6'	SILTY SAND (SM) (A)
6'-20'	CLAYEY SAND (SC) (B)

20' = TOTAL DEPTH

WATER ENCOUNTERED AT 17.5'

TP-28

0-1'	TOPSOIL
1'-7'	FAT CLAY (CH) AND FAT SILTY CLAY (CH/MH) (A+B)
7'9'	SILTY SAND (SM), ORANGE-BROWN (F)
9'-15.7'	SILTSTONE AND SHALE (C+D)
15.7'-16'	SILTSTONE, DARK BLUE GRAY (E)

16' = TOTAL DEPTH

WATER ENCOUNTERED AT 9'

TP-29

0-1'	TOPSOIL
1'-2'	GRAVEL, SOME RED CLAY
2'-10'	MUDDY CLAY, BROWN
10'-15.5'	SHALE, DARK GRAY

15.5' = TOTAL DEPTH

WATER ENCOUNTERED AT 15.5'

TP-30

0-3'	TOPSOIL
3'-17'	CLAY

17'= TOTAL DEPTH

NO WATER INDICATED

TP-31

0-1'	TOPSOIL
1'-1.5'	BROWN SILTY CLAY W/CALICHE
1.5'-3.5'	LIGHT BROWN SILT
3.5'-4.5'	BLACK SILTY CLAY W/SS BOULDERS
4.5'-8'	OLIVE BROWN SILT SHALE
8'-10'	DARK GRAY SILTY CLAY SHALE
10'-10.5'	BROWN SANDSTONE
10.5'-13'	DARK BROWN CLAY SHALE
13'-17.5'	COAL TO SILT SHALE
17.5'-18'	LIGHT BROWN CLAYSTONE

18' = TOTAL DEPTH

WATER ENCOUNTERED AT 17.5'

TP-32

0-1.5'	TOPSOIL
1.5'-12'	SAND (SP) LIGHT BROWN
12'-16'	CLAYSTONE, DARK GRAY
16'-17'	SILTY SANDSTONE, GRAY

17' = TOTAL DEPTH

NO WATER INDICATED

TP-33

0-1.5'	TOPSOIL
1.5'-5.5'	SILT, LIGHT BROWN
5.5'-7.5'	SAND, (SP) SALT & PEPPER GRAY
7.5'-9'	CLAY SHALE, GRAY
9'-15'	SHALE, MEDIUM BROWN
15'-15.5'	SANDY SILTSTONE, GRAY

15.5' = TOTAL DEPTH

NO WATER INDICATED

APPENDIX B. WELL LOGS AND MONITORING WELL COMPLETION FORMS

TEST BORING LOG

Location: (Twp, Rng, Sec) [illegible] Well number UDD 5/P-5

Location: (N,S) _____ (E,W) _____ Date(s) 4/13/85

Surface Elevation 2551 [illegible] Logged By B. SIEGMUND

Driller SHARP DRILLING, SIDNEY MT. Drill Method AIR ROTARY

Hole Diam. 7 7/8" TO 10', 5 3/4" TO T.D. Casing (type, depth) 1 25' PVC

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2551.25		
5			POORLY SORTED SILT SAND AND GRAVELY ROUNDED AND POLISHED, O2
10	2541.44		
15			SLIGHTLY STICKY, SANDY, SILTY CLAY, LIGHT GRAY, MINOR ANGULAR GRAVEL AT TOP OF BED, DRILLER INJECTED 2-3 GALLONS OF WATER TO CLEAN HOLE, LESS STICKY AT BOTTOM OF BED
20	2526.44		MEDIUM TO FINE-GRAINED, POORLY SORTED, BROWNISH GRAY SAND, RESISTANT, PINK-RED SANDSTONE (WITH Fe NODULES?) AT 23.5'-24.5', MAINSTONES 0.8' THICK
25			STICKY, GRAY TO TAN CLAY
30	2516.44		INTERBEDDED GRAY CLAY AND SHALE, GRADES TO REDDISH-BROWN OR RUST IN COLOR IN SOME BEDS, RESISTANCE VARIES.
35			RESISTANT TAN-GRAY SANDSTONE (CAVED AT END OF DAY AT 35')
			SILTY GRAY SHALE
40	2504.44		TAN-GRAY SANDSTONE
			SILTY GRAY SHALE
45			TAN-GRAY SANDSTONE
			SANDY, SILTY, LIMESTONE OR DOLOMITE
50	2488.44		DARK, LOOSE SAND, LIGHT GRAY

Dansoben & Associates, Inc. PAGE 1 OF 2

CONSULTING ENGINEERS
4000 11th Avenue, Suite 1A
Helena, Montana

TEST BORING LOG

Project Name UNIFIED DISPOSAL
Project number 93-06
Location (TWP, RNG, Sec.) 32N, 18E, N.E. SEC. 6
Well number UDD-5/P-5
Location (N,S) _____ (E,W) _____
Date(s) 4/14/93
Surface Elevation 2591.76 (TOC)
Logged By B. SIEGMUND
Driller SHARP DRILLING, SIDNEY, MT.
Drill Method AIR ROTARY
Hole Dia. 5 3/4" TO 18', 4 3/4" TO T.D.
Casing (type, depth) 1.25" PVC

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION	WELL CONST. DETAILS
	2588.68		POORLY SORTED SILT SAND AND GRAVEL, ROUNDED AND POLISHED, Qg	
5				
10	2578.68		SLIGHTLY STICKY, SANDY, SILTY CLAY, LIGHT GRAY, MINOR ANGULAR GRAVEL AT TOP OF BED, DRILLER INJECTED 3-5 GALLONS OF WATER TO CLEAR HOLE, LESS STICKY AT BOTTOM OF BED.	
15				
20	2568.68		MEDIUM TO FINE-GRAINED, POORLY SORTED, BROWNISH GRAY SAND, RESISTANT, RUST-RED SANDSTONE (WITH Fe NODULES?) AT 23.5'+24.5', SANDSTONES < 0.5' THICK	
25			STICKY, GRAY TO TAN CLAY	
30	2558.68		INTERBEDDED GRAY CLAY AND SHALE, GRADES TO REDDISH-BROWN OR RUST IN COLOR IN SOME BEDS, RESISTANCE VARIES.	
35			RESISTANT TAN-GRAY SANDSTONE (CAVED BY END OF DAY AT 34')	
			SILTY GRAY SHALE	
40	2548.68		TAN-GRAY SANDSTONE	
			SILTY GRAY SHALE	
45			TAN-GRAY SANDSTONE	
			SANDY, SILTY, LIMESTONE OR DOLOMITE	
50	2538.68		DAMP, LOOSE SAND, LIGHT GRAY	

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•HELENA, MONTANA•

TEST BORING LOG

Project Name: [illegible] DISCOVERY
Location (TW, RW, Sec): [illegible] R.E. 120.6
Location (N,E): _____ (E,W)
Surface Elevation: [illegible] (TUCC)
Driller: [illegible] DRILLING, [illegible]
Hole Size: [illegible] 10 [illegible]

Project number: [illegible]
Well number: [illegible]
Date(s): [illegible]
Logged By: [illegible]
Drill Method: [illegible]
Casing (type, depth): [illegible]

Depth (Feet)	Water Data (Feet)	Sample No.	Materials Description
0	[illegible]		POORLY SORTED SILT SAND AND GRAVEL, ROUNDED AND SUBROUNDED, DG
5			
10	[illegible]		SILICATED STICKY, SANDY, SILTY CLAY, LIGHT GRAY, MINOR AMOUNTS OF ALL 4 TOP, DG DESC; DRILLING IMPEDED 3- [illegible] OF DRILLING TO CLEAN HOLE, CLEAN STICKY AT BOTTOM OF BED.
15			
20	[illegible]		WEATHER TO FINE-GRAINED, POORLY SORTED, SCHISTOSE GRAY SAND, DEEP TAN, SILT-RICH (MORTAR TEXTURE) FT ADVANCED AT [illegible] , SAND/GRAVEL - 0.5" TUBES
25			EFFORT: GRAY TO TAN CLAY
30	[illegible]		WEATHERED GRAY CLAY, VERY SHALE, SHARPLY DESTROYS DRILL BIT IN DRILLING IN ZONE BEST, [illegible] VARIES
35			REGISTRAN TAN-GRAY SANDSTONE FOLDED BY END OF DAY AT 34.)
40	[illegible]		SILTY GRAY SHALE
45			TAN-GRAY SANDSTONE
			SILTY GRAY SHALE
			TAN-GRAY SANDSTONE
			SANDY, SILTY, LIMESTONE OR DOLOMITE
			DARK LOOKS SAND, LIGHT GRAY

Dimsdale & Associates, Inc.
[illegible]

PAGE 1 OF 2

TEST BORING LOG

Project Name UNIFIED DISPOSAL
Location T32N, R18E, SW SE NW Sec.6
Location (N,S) 180N (E,W) 2920E
Surface Elevation 2606.5
Driller SHARP DRILLING, SIDNEY, MT.
Hole Dia. 4 3/4"

Project number 93-06
Well number UDD-6
Date(s) 4/14/93
Logged By B. SIEGMUND
Drill Method AIR ROTARY
Casing (type, depth) N/A

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2606.5		TOPSOIL, DARK BROWN SANDY LOAM
5			GLACIAL DEPOSITS, DRIFT AND GLACIOFLUVIAL SILT, SAND AND GRAVEL.
10	2596.5		
15			
20	2586.5		DRY MEDIUM TO FINE-GRAINED BROWN SAND CONTACT WITH CRETACEOUS JUDITH RIVER FORMATION
25			INTERBEDDED LIGHT GRAY SILT AND CLAY
30	2576.5		
35			LIGHT GRAY-TAN, MEDIUM TO FINE GRAINED, POORLY SORTED SAND
40	2566.5		ca,mg CARBONATE SANDSTONE GRAY-TAN SAND AS ABOVE
45			MEDIUM TO LIGHT GRAY SILTY CLAY
50	2556.5		

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TEST BORING LOG

Project Name UNIFIED DISPOSAL

Project number 93-06

Well number UDD-6

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2556.5		MEDIUM TO LIGHT GRAY SILTY CLAY
			VERY FINE-GRAINED GRAY SILTY SAND
55			MEDIUM TO DARK GRAY SILTY CLAY
60	2546.5		
65			
			MEDIUM BROWNISH-GRAY SILTY CLAY
70	2536.5		
			MEDIUM TO DARK GRAY SILTY CLAY
75			
80	2526.5		
			LIGHT GRAY, POORLY SORTED, FINE TO VERY FINE GRAINED SAND
85			
			MEDIUM TO DARK GRAY SILTY CLAY
90	2516.5		
			VERY FINE GRAINED, LIGHT GRAY SAND INTERBEDDED WITH LIGHT GRAY TO GRAY-BROWN SANDY SILTY CLAY AND CLAYEY, SILTY SAND, CLAY AT 100', ALL SLIGHTLY DAMP
95			
100	2506.5		
			VERY FINE-GRAINED, LIGHT GRAY SAND, SLIGHTLY DAMP.
105			

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TEST BORING LOG

Project Name UNIFIED DISPOSAL

Project number 93-06

Well number UDD-6

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
110	2496.5		LIGHT GRAY, VERY FINE GRAINED, POORLY SORTED, SILTY SAND, SLIGHTLY DAMP
115			
120	2486.5		MEDIUM GRAY SILTY CLAY T.D. ALL OF THE SAND FROM 90'-117' IS DAMP, MOST JUST BARELY SO. AFTER SHUTTING DOWN COMPRESSOR AT 104' FOR 20 MINUTES, MIST WAS BLOWN OUT OF THE HOLE. THE EXACT SOURCE IS NOT CLEAR. HOLE PLUGGED WITH MEDIUM PELLET BENTONITE TO 75', #8 GRANULAR BENTONITE TO 3', CUTTINGS AND SOIL 3' TO SURFACE.

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TEST BORING LOG

Project Name: UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.): 32N, 18E, SE, NW, 6
Grid (N,S) _____ (E,W) _____
Surface Elevation: 2610
Driller: SHARP DRILLING, SIDNEY, MT.
Hole Dia.: 4 3/4"

Project number: 93-06
Well number: UDD-7
Date(s): 4/14/93
Logged By: B.L.S.
Drill Method: AIR ROTARY
Casing (type, depth): N/A

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2610		TOPSOIL, SANDY, SILTY, LOAM
5			
10	2600		LIGHT BROWN TO TAN, POORLY SORTED, SILTY, GRAVELLY SAND AND SILT, GLACIAL DRIFT WITH THIN GLACIO-FLUVIAL SAND BEDS, Qg
15			
20	2590		SLIGHTLY STICKY
			WHITE, CLEAN, MEDIUM GRAINED SAND, Qg
			GRAVEL
25			GRAY, FINE GRAINED SAND
30	2580		BROWN, SILTY CLAY
			GRAY-BROWN SAND
35			BROWN, ORGANIC CLAY WITH SHELL BED
			LIGHT BROWN, VERY FINE GRAINED SAND
			GRAY SILTY SHALE
40	2570		GRAVEL
			GRAY, SILTY SHALE
45			LIGHT TAN TO LIGHT GRAY, VERY FINE GRAINED SAND & SILTY SAND
			BROWNISH TAN, RESISTANT SANDSTONE
50	2560		LOOSE SAND, AS ABOVE

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TEST BORING LOG

Project Name UNIFIED DISPOSAL DIST.

Project number 93-06

Well number UDD-7

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2560		LIGHT TAN TO LIGHT GRAY, VERY FINE GRAINED SAND & SILTY SAND
55			SILTY GRAY CLALY
60	2550		FINE GRAINED SILTY GRAY SAND
65			MEDIUM GRAY CLAY, FAIRLY RESISTANT 62-67'
70	2540		
75			
80	2530		
85			
90	2520		
			VERY FINE GRAINED GRAY SAND, LOOSE
95			VERY RESISTANT, CARBONATE RICH, SILTY SANDSTONE
			VERY FINE GRAINED GRAY SAND, LOOSE
100	2510		
			MEDIUM GRAY SILTY SHALE

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TEST BORING LOG

Project Name UNIFIED DISPOSAL DIST. Project number 93-06
Well number UDD-7

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			GRAY, SANDY, SILTY CLAY
110	2500		
			VERY RESISTANT, Ca - CARBONATE RICH SANDSTONE
115			GRAY, SANDY, SILTY CLAY
120	2490		
			SHUT DOWN COMPRESSOR UPON PENETRATING MOIST SAND BEDS, BUT NO MOISTURE WAS DETECTED ANYWHERE IN THE HOLE

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TEST BORING LOG

Project Name UNIFIED DISPOSAL
Project number 93-06
Location T32N, R18E, NE SW Sec.6
Well number UDD-8/MW-7
Location (N,S) _____ (E,W) _____
Date(s) 4/15/93
Surface Elevation 2601.5/COLLAR 2605.88
Logged By B. SIEGMUND
Driller SHARP DRILLING, SIDNEY, MT.
Drill Method AIR ROTARY
Hole Dia. 4 3/4"
Casing (type, depth) 2" PVC, 16'

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2601.5		FAIRLY CLEAN, BROWN TO TAN, MEDIUM TO COARSE GRAINED SAND AND MINOR GRAVEL, Qg
5			
10	2591.5		SAND AND GRAVEL, PEA TO COBBLE SIZED CLASTS, INJECTED WATER TO KEEP HOLE OPEN.
15			MEDIUM GRAY SILTY SHALE
20	2581.5		SANDY LIMESTONE OR DOLOMITEM, LIGHT GRAY
			MEDIUM GRAY SILTY SHALE
25			
			FINE GRAINED, SILTY, GRAY SAND
30	2571.5		
35			MEDIUM GRAY SILTY SHALE
40	2561.5		SANDY, SILTY LIMESTONE OR DOLOMITE, LIGHT GRAY
45			HOLE CAVED AT 16', WHICH PROBABLY REPRESENTS THE TOP OF THE WATER TABLE. A WELL WAS COMPLETED IN THIS HOLE WITH GREAT DIFFICULTY, THERE APPEARS TO BE WATER FROM 16' TO 17'. SEE DHES MONITORING WELL CONSTRUCTION FORM FOR DETAILS.

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•HELENA, MONTANA•

State of Montana
Department of Health
and Environmental Sciences

Route to: Solid Waste ☒ Haz. Waste ☐ Underground Tanks ☐ Other ☐ _____

MONITORING WELL CONSTRUCTION

Facility/Project Name: UNIFIED DISPOSAL DISTRICT

Facility License: 222

Type of Well: Water Table Observation Well ☐ Piezometer ☐

Distance Well is From Waste/Source Boundary: 25 ft

Well a Point of Standards Application? ☐ Yes ☐ No

Local Grid Location of Well: _____ ft ☐N ☐S _____ ft ☐E ☐W

Grid Origin Location: Lat. _____ Long. _____ or St. Plane _____ ft N _____ ft S

Section Location of Waste/Source: E1/2 SEC 6, T32N, R18E ☐E ☐W

Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☒ Not Known

Well Name: MW - 7

MT Unique Well Number: DHES Well Name:

Date Well Installed: 04/15/93 (mm dd yy)

Well Installed By: (Person's Name and Firm) JOHN SHARP, SHARP DRILLING

BRUCE SIEGMUND, DAMSCHEN + A

. Protective pipe, top elevation: 2605.88 ft. MSL

. Well casing, top elevation: 2605.71 ft. MSL

. Land Surface elevation: 2601.5 ft. MSL

. Surface seal, bottom: 2 ft. MSL or 3.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☒ GW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☒ No

14. Drilling method used: Rotary ☒ Hollow Stem Auger ☐ Other ☐ _____

15. Drilling fluid used: Water X Air ☒ Drilling Mud ☐ None ☐
INJECTED WATER @ 11'

16. Drilling additives used? ☐ Yes ☒ No

Describe _____

17. Source of water: CITY OF HAVRE MUNICIPAL

. Bentonite seal, top: ____ ft. MSL or 9 ft.

Fine sand, top: ____ ft. MSL or 10 ft.

. Filter pack, top: ____ ft. MSL or 11 ft.

. Screen joint, top: ____ ft. MSL or 11 ft.

Well bottom: ____ ft. MSL or 16 ft.

Filter pack, bottom: ____ ft. MSL or 16 ft.

Borehole bottom: ____ ft. MSL or 17 ft.

Borehole, diameter: 4.75 in.

. O.D. well casing: ____ in.

I.D. well casing: 2.0 in.

BOREHOLE CAVED DURING INSTALLATION; MATERIAL COMPRISES COARSE SAND + GRAVEL.

1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
a. Inside diameter: 4 in.
b. Length: 5 ft.
c. Material: Steel ☒ Other ☐ _____
d. Additional protection? ☐ Yes ☐
If yes, describe: _____
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐ _____
4. Material between well casing and protective pipe: Bentonite ☒ Annular space seal ☐ Other ☐ _____
5. Annular space seal: a. Granular bentonite ☒
b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
d. ____ % bentonite . . . . . Bentonite cement grout ☐
e. ____ Ft^3 volume added for any of the above
f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
b. ☐ 1/4 in. ☐ 3/8 in. ☒ 1/2. Bentonite pellets ☒
c. _____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
a. CSSI COLORADO, 20/40
b. Volume added 0.1 ft^3
8. Filter pack material: Manufacturer, product name & mesh size
a. CSSI COLORADO
b. Volume added 6 BAGS ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐ _____
10. Screen material: FLUSH THREADED PVC SCH 40
a. Screen type: Factory cut ☒ Continuous slot ☐ Other ☐ _____
b. Manufacturer: JOHNSON
c. Slot size: 0.020 in.
d. Slotted length: 5 ft.
10. Screen material: None ☐ Other ☐ _____

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: [signature] Firm: DAMSCHEN + ASSOC.

State of Montana
Department of Health
and Environmental Sciences

Route to: Solid Waste ☒ Haz. Waste ☐ SuperFund/CECRA ☐ Underground Tanks ☐ Other ☐ _____

MONITORING WELL DEVELOPMENT

Facility/Project Name	County Name	Well Name
UNIFIED DISPOSAL DIST. LF	BLAINE	M-7

Facility License Number	County Code	MT Unique Well Number	DHES Well Number
222			

1. Can this well be purged dry? ☐ Yes ☐ No

2. Well development method
   - surged with bailer and bailed ☐
   - surged with bailer and pumped ☐
   - surged with block and bailed ☐
   - surged with block and pumped ☐
   - surged with block, bailed and pumped ☐
   - compressed air ☐
   - bailed only ☐
   - pumped only ☐
   - pumped slowly ☐
   - Other _____ ☐

3. Time spent developing well _____ min.

4. Depth of well (from top of casing) _____.__ ft.

5. Inside diameter of well _____.__ in.

6. Volume of water in filter pack and well casing _____.__ gal.

7. Volume of water removed from well _____.__ gal.

8. Volume of water added (if any) _____.__ gal.

9. Source of water added _____

10. Analysis performed on water added? ☐ Yes ☐ No
    (If yes, attach results)

	Before Development	After Development
11. Depth to Water (from top of well casing)	a. _____.___ ft.	_____.___ ft.
Date	b. __/__/__ (mm dd yy)	__/__/__ (mm dd yy)
Time	c. __:__ ☐ a.m. ☐ p.m.	__:__ ☐ a.m. ☐ p.m.
12. Sediment in well bottom	___.__ inches	___.__ inches
13. Water clarity	Clear ☐ Turbid ☐ (Describe)	Clear ☐ Turbid ☐ (Describe)

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids	_____.__ mg/l	_____.__ mg/l
15. COD	_____.__ mg/l	_____.__ mg/l

16. Additional comments on development

WELL HAD NO SIGNIFICANT WATER - PURGED DRY W/ NO RECOVERY. GRAVEL MOST LIKELY CAVED TO TOP OF WATER LEVEL DURING INSTALLATION

Well developed by: (Person's Name and Firm)

Name: BRUCE SIEGMUND

Firm: DAMSCHEN + ASSOC.

I hereby certify that the above information is true and correct to the best of my knowledge

Signature: Bruce Siegmund

Print Initials: BS

Firm: DAMSCHEN + ASSOC

Note: Shaded areas are for DHES use only. See instructions for more information including a list of county codes.

TEST BORING LOG

Project Name UNIFIED DISPOSAL
Location T32N, R18E, NE SW Sec.6
Location (N,S) _____ (E,W) _____
Surface Elevation 2601.32/COLLAR=2605.19
Driller SHARP DRILLING, SIDNEY, MT.
Hole Dia. 4 3/4"

Project number 93-06
Well number UDD-9/MW-3
Date(s) 4/15/93
Logged By B. SIEGMUND
Drill Method AIR ROTARY
Casing (type, depth) 2" PVC, 60'

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	260		
5			LIGHT BROWN-GRAY SAND
10	259		
			COARSE SAND AND GRAVEL
15			
20	258		MEDIUM GRAY SILTY CLAY
25			
30	257		VERY FINE GRAINED GRAY SAND
35			LIGHT GRAY SILTY CLAY GRADING TO DARKER GRAY CLAY WITH DEPTH
40	256		▽ VERY FINE GRAINED, GRAY, SILTY SAND MAROON, CARBON RICH CLAY GRAY SILTY CLAY
45			GRAY FINE GRAINED SAND GRAY, SILTY CLAY
50	255		VERY FINE GRAINED SILTY SAND

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•HELENA, MONTANA•

TEST BORING LOG

Project Name UNIFIED DISPOSAL

Project number 93-06

Well number UDD-9/MW-3

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			GRAY, FINE GRAINED SILTY SAND
			LIGHT GRAY LIMEY SANDSTONE/SANDY CARBONATE, VERY RESISTANT
55			
			VERY FINE GRAINED, SILTY SAND, MOIST, WATER CAN BE BLOWN FROM HOLE AFTER LESS THAN 10 MINUTES.
60	2541		GRAY SILTY CLAY.
			TOP 18' DRILLED ON WATER MIXED WITH TWO 50 LB. SACKS OF BENTONITE GEL. 6" STEEL CASING WAS DRIVEN TO 18' TO CASE OFF WATER IN UPPERMOST GRAVEL. DRILLED TO 20' ON AIR, SHUT DOWN COMPRESSOR FOR A SHORT TIME. UPON BLOWING AIR INTO THE HOLE, NO WATER WAS RETURNED. THE REMAINDER OF THE HOLE WAS DRILLED ON AIR.
65			
			HOLE WAS COMPLETED AS A MONITORING WELL. SEE DHES COMPLETION FORMS FOR CONSTRUCTION DETAILS.

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State of Montana
Department of Health
and Environmental Sciences

Route to: Solid Waste ☒ Haz. Waste ☐ Underground Tanks ☐ Other ☐ _____

MONITORING WELL CONSTRUCTION

Facility/Project Name: UNIFIED DISPOSAL DIST. LF

Facility License: 222

Type of Well: Water Table Observation Well ☐ Piezometer ☐

Distance Well is From Waste/Source Boundary: 25 ft

Is Well a Point of Standards Application? ☐ Yes ☐ No

Local Grid Location of Well: _____ ft ☐N ☐S _____ ft ☐E ☐W

Grid Origin Location: Lat. ___ ___ ___ Long. ___ ___ ___ or

St. Plane _____ ft N _____ ft S

Section Location of Waste/Source: E 1/2 SEC. 6 T 32N R 18 E ☐E ☐W

Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known

Well Name: MW-3

MT Unique Well Number | DHES Well Name

Date Well Installed: 04/15/93 (mm dd yy)

Well Installed By: (Person's Name and Firm) JOHN SHARP, SHARP DRILLING, BRUCE SIEGMUND, DAMSCHEN ASS

A. Protective pipe, top elevation: 2605.19 ft. MSL

B. Well casing, top elevation: 2604.49 ft. MSL

C. Land Surface elevation: 2601.32 ft. MSL

D. Surface seal, bottom: ____.__ ft. MSL or 3.__ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☒ GW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☒ No

14. Drilling method used: Rotary ☒ Hollow Stem Auger ☐ Other ☐ _____ TO 20'

15. Drilling fluid used: Water ☒ Air ☐ Drilling Mud ☐ None ☐

16. Drilling additives used? ☐ Yes ☐ No

Describe _____

17. Source of water: CITY OF HAVRE MUNICIPAL

E. Bentonite seal, top: ____.__ ft. MSL or 51.__ ft.

F. Fine sand, top: ____.__ ft. MSL or 52.__ ft.

G. Filter pack, top: ____.__ ft. MSL or 53.__ ft.

H. Screen joint, top: ____.__ ft. MSL or 53.5 ft.

I. Well bottom: ____.__ ft. MSL or 58.5 ft.

J. Filter pack, bottom: ____.__ ft. MSL or 59.0 ft.

K. Borehole bottom: ____.__ ft. MSL or 59.0 ft.

L. Borehole, diameter: 4.75 in.

M. O.D. well casing: ____.__ in.

N. I.D. well casing: 2.__ in.

1. Cap and lock? ☒ Yes ☐ No

2. Protective cover pipe: 5' LONG, 4" SQUARE, INS
a. Inside diameter: 6.__ in.
b. Length: 20.__ ft.
c. Material: CASED OFF GRAVEL w/ 6" STEEL PIPE TO 18' Steel ☒ Other ☐
d. Additional protection? – ☐ Yes ☐
If yes, describe: _____

3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐

4. Material between well casing and protective pipe: Bentonite ☒ Annular space seal ☐ Other ☐

5. Annular space seal: a. Granular bentonite ☒
b. _____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
c. _____ Lbs/gal mud weight . . . Bentonite slurry ☐
d. _____ % bentonite . . . . . Bentonite cement grout ☐
e. _____ Ft^3 volume added for any of the above
f. How installed: Tremie ☒ Tremie pumped ☐ Gravity ☒

6. Bentonite seal: a. Bentonite granules ☐
b. ☐ 1/4 in. ☐ 3/8 in. ☒ 1/2. Bentonite pellets ☒
c. _____ Other ☐

7. Fine sand material: Manufacturer, product name & mesh size
a. CSSI COLORADO 20/40
b. Volume added 0.1+ ft^3

8. Filter pack material: Manufacturer, product name & mesh size
a. CSSI COLORADO
b. Volume added 1 326 ft^3

9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐

10. Screen material: SCH 40 PVC
a. Screen type: Factory cut ☒ Continuous slot ☐ Other ☐
b. Manufacturer: JOHNSON
c. Slot size: 0.010 in.
d. Slotted length: 5.__ ft.

10. Screen material: None ☐ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: Bruce L. Siegmund | Firm: DAMSCHEN – ASSOC.

State of Montana
Department of Health
and Environmental Sciences

Route to: Solid Waste ☐ Haz. Waste ☐ SuperFund/CECRA ☐ Underground Tanks ☐ Other ☐ _____

MONITORING WELL DEVELOPMENT

Facility/Project Name	County Name	Well Name
UNIFIED DISPOSAL DIST LF	BLAINE	MW-3

Facility License Number	County Code	MT Unique Well Number	DHES Well Number
222			

1. Can this well be purged dry? ☒ Yes ☐ No

2. Well development method
   - surged with bailer and bailed ☒
   - surged with bailer and pumped ☐
   - surged with block and bailed ☐
   - surged with block and pumped ☐
   - surged with block, bailed and pumped ☐
   - compressed air ☐
   - bailed only ☐
   - pumped only ☐
   - pumped slowly ☐
   - Other _____ ☐

3. Time spent developing well 45 min.

4. Depth of well (from top of casing) 62.8 ft.

5. Inside diameter of well 2.__ in.

6. Volume of water in filter pack and well casing 3+.__ gal.

7. Volume of water removed from well 5.__ gal.

8. Volume of water added (if any) 0.__ gal.

9. Source of water added _____

10. Analysis performed on water added? ☒ Yes ☐ No
(If yes, attach results)

	Before Development	After Development
11. Depth to Water (from top of well casing)	a. 43.83 ft.	51.83 ft. STILL RECOVERING
Date	b. 04/18/93 (mm dd yy)	04/18/93 (mm dd yy)
Time	c. 12:10 ☐ a.m. ☒ p.m.	1:00 ☐ a.m. ☒ p.m.
12. Sediment in well bottom	___.__ inches	___.__ inches
13. Water clarity	Clear ☐ Turbid ☒ (Describe) GREY SILT	Clear ☐ Turbid ☒ (Describe) GREY SILT

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids	280.__ mg/l	____.__ mg/l
15. COD	____.__ mg/l	____.__ mg/l

16. Additional comments on development – AFTER DEVELOPMENT:

pH = 7.70 su
T = 50.9° F
SC = 14,550 umho

Well developed by: (Person's Name and Firm)

Name: BRUCE L. SIEGMUND

Firm: DAMSCHEN + ASSOC

I hereby certify that the above information is true and correct to the best of my knowledge

Signature: Bruce L. Siegmund

Print Initials: BLS

Firm: DAMSCHEN + ASSOC.

Note: Shaded areas are for DHES use only. See instructions for more information including a list of county codes.

TEST BORING LOG

Project Name UNIFIED DISPOSAL
Location T32N, R18E, SW NW Sec.6
Location (N,S) _____ (E,W) _____
Surface Elevation 2536.77/COLLAR=2539.00
Driller SHARP DRILLING, SIDNEY, MT.
Hole Dia. 4 3/4"

Project number 93-06
Well number UDD-10/MW-5
Date(s) 4/15/93
Logged By B. SIEGMUND
Drill Method AIR ROTARY
Casing (type, depth) 2" PVC, 30'

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2536.77		LIGHT TAN SILT
			MAROON-BROWN, ORGANIC RICH CLAY
			SHELL BED
5			GRAY-BROWN CLAY
10	2526.77		GRAY-BROWN FINE SAND
15			GRAY-BROWN CLAY INTERBEDDED WITH MAROON-BROWN CLAY, GRADES TO IRON STAINED GRAY-BROWN CLAY, SLIGHTLY STICKY, IRON STAINS ON PARTINGS.
20	2516.77		▽
25			DRY, LIGHT GRAY SILTY CLAY
			MEDIUM GRAY, VERY FINE GRAINED SILTY SAND.
30	2506.77		MOIST SILTY CLAY
			SEE DHES MONITORING WELL CONSTRUCTION FORMS FOR COMPLETION DETAILS

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State of Montana
Department of Health
and Environmental Sciences

Route to: Solid Waste ☒ Haz. Waste ☐
Underground Tanks ☐ Other ☐ _____

MONITORING WELL CONSTRUCTION

Facility/Project Name: UNIFIED DISPOSAL DIST. LF

Facility License: 222

Type of Well: Water Table Observation Well ☐ Piezometer ☐

Distance Well is From Waste/Source Boundary: ~75 ft

Is Well a Point of Standards Application? ☐ Yes ☐ No

Local Grid Location of Well: _____ ft ☐N ☐S _____ ft ☐E ☐W

Grid Origin Location: Lat. _____ Long. _____ or St. Plane _____ ft N _____ ft S

Section Location of Waste/Source: E 1/2 SEC 6, T32 N, R18E ☐E ☐W

Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known

Well Name: MW-5

MT Unique Well Number | DHES Well Name

Date Well Installed: 04/15/93 (mm dd yy)

Well Installed By: (Person's Name and Firm) JOHN SHARP, SHARP DRILLING
BRUCE SIEGMUND, DAMSCHEN + ASSOC

A. Protective pipe, top elevation 2539.00 ft. MSL

B. Well casing, top elevation 2538.85 ft. MSL

C. Land Surface elevation 2536.62 ft. MSL

D. Surface seal, bottom ____.__ ft. MSL or 3.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ GW ☐ SP ☐
SM ☐ SC ☐ ML ☒ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☒ No

14. Drilling method used: Rotary ☒ Hollow Stem Auger ☐ Other ☐ _____

15. Drilling fluid used: Water ☐ Air ☒ Drilling Mud ☐ None ☐

16. Drilling additives used? ☐ Yes ☐ No
Describe _____

17. Source of water: _____

E. Bentonite seal, top ____.__ ft. MSL or 23.__ ft.

F. Fine sand, top ____.__ ft. MSL or N/A.__ ft.

G. Filter pack, top ____.__ ft. MSL or 24.__ ft.

H. Screen joint, top ____.__ ft. MSL or 24.5 ft.

I. Well bottom ____.__ ft. MSL or 29.5.__ ft.

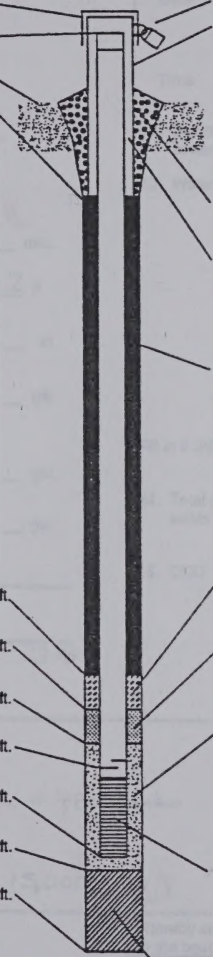
J. Filter pack, bottom ____.__ ft. MSL or 30.__ ft.

K. Borehole bottom ____.__ ft. MSL or 30.__ ft.

L. Borehole, diameter ____.__ in.

M. O.D. well casing ____.__ in.

N. I.D. well casing ____.__ in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
a. Inside diameter: 4.__ in.
b. Length: 5.__ ft.
c. Material: Steel ☒ Other ☐ _____
d. Additional protection? ☐ Yes ☐
If yes, describe: _____
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐ _____
4. Material between well casing and protective pipe: Bentonite ☒ Annular space seal ☐ Other ☐ _____
5. Annular space seal: a. Granular bentonite ☒
b. _____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
c. _____ Lbs/gal mud weight . . . Bentonite slurry ☐
d. _____ % bentonite . . . . . Bentonite cement grout ☐
e. _____ ft^3 volume added for any of the above
f. How installed: Tremie ☐ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
b. ☐ 1/4 in. ☐ 3/8 in. ☒ 1/2. Bentonite pellets ☒
c. _____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
a. N/A
b. Volume added _____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
a. CSSI COLORADO 20/40
b. Volume added 1 BAG ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐ _____
10. Screen material: SCH40 PVC
a. Screen type: Factory cut ☒ Continuous slot ☐ Other ☐ _____
b. Manufacturer: JOHNSON
c. Slot size: 0.010 in.
d. Slotted length: 5.__ ft.
10. Screen material: None ☐ Other ☐ _____

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm
Bruce J. Sig	DAMSCHEN + ASSOC.

State of Montana
Department of Health
and Environmental Sciences

Route to: Solid Waste ☒ Haz. Waste ☐ SuperFund/CECRA ☐ Underground Tanks ☐ Other ☐ _____

MONITORING WELL DEVELOPMENT

Facility/Project Name	County Name	Well Name
UNIFIED DISPOSAL DIST LF	BLAINE	MW-5

Facility License Number	County Code	MT Unique Well Number	DHES Well Number
222			

1. Can this well be purged dry? ☒ Yes ☐ No

2. Well development method
   - surged with bailer and bailed ☒
   - surged with bailer and pumped ☐
   - surged with block and bailed ☐
   - surged with block and pumped ☐
   - surged with block, bailed and pumped ☐
   - compressed air ☐
   - bailed only ☐
   - pumped only ☐
   - pumped slowly ☐
   - Other _____ ☐

3. Time spent developing well 45 min.

4. Depth of well (from top of casing) 32.2 ft.

5. Inside diameter of well 2.__ in.

6. Volume of water in filter pack and well casing ~1.5.__ gal.

7. Volume of water removed from well 3.__ gal.

8. Volume of water added (if any) ___.__ gal.

9. Source of water added _____

10. Analysis performed on water added? ☒ Yes ☐ No
    (If yes, attach results)

	Before Development	After Development
11. Depth to Water (from top of well casing)	a. 24.38 ft.	23.88 ft.
Date	b. 04/18/93 (mm dd yy)	04/19/93 (mm dd yy)
Time	c. 4:00 ☐ a.m. ☒ p.m.	8:30 ☒ a.m. ☐ p.m.
12. Sediment in well bottom	___.__ inches	___.__ inches
13. Water clarity	Clear ☐ Turbid ☒	Clear ☐ Turbid ☐
	(Describe) YELLOWISH-GREY	(Describe) YELLOWISH-GREY

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids	_____.__ mg/l	37.__ mg/l
15. COD	_____.__ mg/l	15.__ mg/l

16. Additional comments on development

pH = 7.32 S.U.
SC = OFF SCALE - ½ DILUTION = 7800 µmho
T = 50.7° F
TOTAL DISSOLVED SOLIDS = 15,000 mg/l

Well developed by: (Person's Name and Firm)

Name: BRUCE SIEGMUND

Firm: DAMSCHEN + ASSOC.

I hereby certify that the above information is true and correct to the best of my knowledge

Signature: Bruce J. Siegmund

Print Initials: BLS

Firm: DAMSCHEN + ASSOC.

Note: Shaded areas are for DHES use only. See instructions for more information including a list of county codes.

TEST BORING LOG

Project Name UNIFIED DISPOSAL
Location T32N, R18E, SW NW Sec.6
Location (N,S)_____ (E,W)_____
Surface Elevation 2593
Driller SHARP DRILLING, SIDNEY, MT.
Hole Dia. 4 3/4"

Project number 93-06
Well number UDD-11
Date(s) 4/16/93
Logged By B. SIEGMUND
Drill Method AIR ROTARY
Casing (type, depth) N/A

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2593		TOPSOIL, SANDY LOAM
5			POORLY SORTED SILT AND MEDIUM TO COARSE SAND WITH MINOR GRAVEL, Qg
10	2583		GRAVEL
			COARSE SAND AND GRAVEL, Qg
15			
			SILTY MAROON CLAY WITH ABUNDANT ORGANICS, Fe STAINS ON CLAY PARTINGS.
20	2573		BROWNISH GRAY CLAY
			SILTY MAROON CLAY, AS ABOVE
25			SHELL BED SANDY LIMESTONE OR DOLOMITE FINE GRAINED GRAY SAND
			TAN CLAY
30	2563		TAN SAND
35			TAN SILTY CLAY
40	2553		
45			VERY FINE GRAINED, SILTY, GRAYISH-TAN SAND
	2543		SHELL BED

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TEST BORING LOG

Project Name UNIFIED DISPOSAL Project number 93-06
Well number UDD-11

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2543		MAROON SHALE
			SILTY, MEDIUM GRAY CLAY
55			
			VERY FINE GRAINED, POORLY SORTED, LIGHT GRAY SAND
60	2533		LIMEY SANDSTONE, LIGHT GRAY
			GRAY SAND, AS ABOVE
			SHELL BED
65			GRAY SAND, AS ABOVE
			MAROONISH BROWN SILTY CLAY
70	2523		VERY FINE GRAINED, GRAY SAND
			MAROONISH BROWN SILTY CLAY
75			
			SILTY, LIGHT GRAY CLAY
80	2513		
			MAROON-BROWN SILTY CLAY WITH SCATTERED SHELLS
			LIMEY GRAY SANDSTONE
85			MAROON -BROWN SILTY CLAY
90	2503		SILTY, LIGHT GRAY CLAY
			MAROON -BROWN SILTY CLAY
			SILTY, LIGHT GRAY CLAY
95			MAROON-BROWN SILTY CLAY
			SANDY, SILTY, LIGHT GRAY LIMESTONE/DOLOMITE VERY RESISTANT
100	2493		
			MAROON-BROWN CLAY GRADING TO SILTY, LIGHT GRAY CLAY
105			

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TEST BORING LOG

Project Name UNIFIED DISPOSAL

Project number 93-06

Well number UDD-11

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
110	2483		SILTY LIGHT GRAY CLAY
115			DRY TO T.D. PLUGGED WITH #8 GRANULAR BENTONITE TO 3', FINISHED WITH CUTTINGS AND TOPSOIL.
120	2473		

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TEST BORING LOG

Project Name UNIFIED DISPOSAL
Location T32N, R18E, SW NW Sec.6
Location (N,S) _____ (E,W) _____
Surface Elevation 2603
Driller SHARP DRILLING, SIDNEY, MT.
Hole Dia. 4 3/4"

Project number 93-06
Well number UDD-12
Date(s) 4/17/93
Logged By B. SIEGMUND
Drill Method AIR ROTARY
Casing (type, depth) N/A

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2603		TOPSOIL, SANDY LOAM
5			
10	2593		GRAY-BROWN SAND WITH SCATTERED GRAVEL, LITHIC INCLUSION OF MAROON SHALE NOTED AT 8', GRAVEL BED AT 21', THIS IS DRIFT AND GLACIOFLUVIAL MATERIAL.
15			
20	2583		
25			
30	2573		SANDY BROWN CLAY, STICKY, WITH VERY POOR RETURN, SAMPLE IS NOT REPRESENTATIVE OF CLAY, GRADES TO RUSTY GRAY CLAY AT 30' THEN TO DRY BROWN-GRAY CLAY.
35			LIGHT GRAY SILTY CLAY
40	2563		MATERIAL FALLING DOWN HOLE FROM TOP 25' PINCHED DRILL STEM. HOLE T.D. AT 40'.

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TEST BORING LOG

Project Name UNIFIED DISPOSAL
Location T32N, R18E, SW NW Sec.6
Location (N,S) _____ (E,W) _____
Surface Elevation 2608.43/COLLAR•2611.26
Driller SHARP DRILLING, SIDNEY, MT.
Hole Dia. 4 3/4"

Project number 93-06
Well number UDD-13/MW-4
Date(s) 4/17/93
Logged By B. SIEGMUND
Drill Method AIR ROTARY
Casing (type, depth) 2"PVC, 115

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2608.4		TOPSOIL, SANDY LOAM
5			FINE TO MEDIUM GRAINED BROWN TO TAN SAND WITH STREAKS OF GRAVEL, AS INDICATED, Qg
10	2598.4		
15			
			GRAY BROWN CLAY, SLIGHTLY STICKY, POSSIBLY LITHIC INCLUSION IN GLACIAL DRIFT OR GLACIOLACUSTRINE DEPOSIT.
20	2588.4		
25			
			BROWNISH TAN CLAY, Kir LIMEY GRAY SANDSTONE
30	2578.4		BROWNISH-TAN SILTY CLAY
35			LIGHT GRAY SILTY CLAY
			MEDIUM TO FINE GRAINED SAND, GRAY-BROWN AT TOP OF INTERVAL GRADING TO RUSTY TAN AT BOTTOM
40	2568.4		FINE GRAINED GRAY SILTY SAND, POORLY SORTED.
45			
			LIGHT TO MEDIUM GRAY SILTY CLAY
50			

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TEST BORING LOG

Project Name UNIFIED DISPOSAL Project number 93-06
Well number UDD-13/MW-4

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2558.4		MEDIUM TO DARK GRAY SILTY CLAY
			CARBONATE RICH SANDY SILTSTONE
55			
60	2548.4		
65			LIGHT TO MEDIUM GRAY SILTY CLAY
70	2538.4		
75			
			VERY FINE GRAINED GRAY SAND
			RESISTANT CARBONATE RICH SILTY SANDSTONE
80	2528.4		
			VERY FINE GRAINED GRAY SAND
85			
			INTERBEDDED GRAY AND MAROON CLAY
90	2518.4		
			FINE TO MEDIUM GRAINED GRAY SAND, SLIGHTLY DAMP
			GRAY CLAY
95			
			GRAY SAND AS ABOVE, WITH SEVERAL THIN CARBONATE RICH ZONES.
			GRAY CLAY
100	2508.4		
			FINE- TO MEDIUM-GRAINED GRAY SAND, SLIGHTLY DAMP
			ORGANIC RICH MAROON SHALE GRADING TO GRAY CLAY
105			

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TEST BORING LOG

Project Name UNIFIED DISPOSAL Project number 93-06
Well number UDD-13/MW-4

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
100			GRAY SILTY CLAY
			MAROON CLAY
110	2498.4		SILTY GRAY CLAY
			VERY FINE GRAINED, SILTY GRAY SAND, MOIST
115			SILTY GRAY CLAY
			COMPLETED AS MONITORING WELL, SEE DHES MONITORING WELL CONSTRUCTION FORMS FOR COMPLETION DETAILS.

Damschen & Associates, Inc.
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TEST BORING LOG

Project Name UNLINED DISPOSAL

Project number 23-04
Well number UDD-13MW-4

DEPTH (FEET)	ELEV. (FEET)	SAMPLE NUMBER	MATERIALS DESCRIPTION
100			DARK SILTY CLAY
			MEDIUM CLAY
110	3440.4		SILTY GRAY CLAY
			VERY FINE GRAINED, SILTY GRAY SAND, MOIST
115			SILTY GRAY CLAY
			COMPLETED AS MONITORING WELL, SEE DNRS MONITORING WELL CONSTRUCTION FORMS FOR COMPLETION DETAILS.

Dravo-Lynn & Associates, Inc.
CONSULTING ENGINEERS
1000 LINN STREET, SUITE 11
INDIANAPOLIS, INDIANA

PAGE 3 OF 4

State of Montana
Department of Health
and Environmental Sciences

Route to: Solid Waste ☒ Haz. Waste ☐
Underground Tanks ☐ Other ☐ _____

MONITORING WELL CONSTRUCTION

Facility/Project Name: UNIFIED DISPOSAL DIST LF

Facility License: 222

Type of Well: Water Table Observation Well ☐ Piezometer ☐

Distance Well Is From Waste/Source Boundary: ~50' ft

Is Well a Point of Standards Application? ☐ Yes ☐ No

Local Grid Location of Well: _____ ft ☐ N ☐ S _____ ft ☐ E ☐ W

Grid Origin Location: Lat. _____ Long. _____ or St. Plane _____ ft N _____ ft S

Section Location of Waste/Source: E1/2 SEC 6 T32N, R18E ☐ E ☐ W

Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known

Well Name: MW-4

MT Unique Well Number: DHES Well Name:

Date Well Installed: 04/17/93 (mm dd yy)

Well Installed By: (Person's Name and Firm) JOHN SHARP, SHARP DRILLING
BRUCE SIEGMUND, DAMSCHEN + ASSOC.

A. Protective pipe, top elevation 2611.26 ft. MSL
B. Well casing, top elevation 2611.00 ft. MSL
C. Land Surface elevation 2608.43 ft. MSL
D. Surface seal, bottom 2605.93 ft. MSL or ___.__ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☒ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☒ No

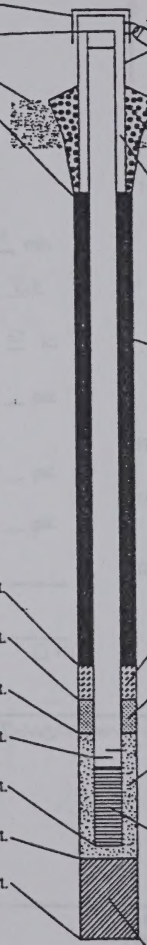
14. Drilling method used: Rotary ☒ Hollow Stem Auger ☐ Other ☐ _____

15. Drilling fluid used: Water ☐ Air ☒ Drilling Mud ☐ None ☐

16. Drilling additives used? ☐ Yes ☐ No
Describe _____

17. Source of water: _____

E. Bentonite seal, top ___.__ ft. MSL or 108.__ ft.
F. Fine sand, top ___.__ ft. MSL or N/A.__ ft.
G. Filter pack, top ___.__ ft. MSL or 109.__ ft.
H. Screen joint, top ___.__ ft. MSL or 110.0 ft.
I. Well bottom ___.__ ft. MSL or 115.0 ft.
J. Filter pack, bottom ___.__ ft. MSL or 115.5 ft.
K. Borehole bottom ___.__ ft. MSL or 115.5 ft.
L. Borehole, diameter 4.75 in.
M. O.D. well casing ___.__ in.
N. I.D. well casing 2.__ in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
a. Inside diameter: 4.__ in. SQUARE
b. Length: __.__ ft.
c. Material: Steel ☒ Other ☐ _____
d. Additional protection? ☐ Yes ☐
If yes, describe: _____
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐ _____
4. Material between well casing and protective pipe: Bentonite ☒ Annular space seal ☐ Other ☐ _____
5. Annular space seal: a. Granular bentonite ☒
b. _____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
c. _____ Lbs/gal mud weight . . . Bentonite slurry ☐
d. _____ % bentonite . . . . . Bentonite cement grout ☐
e. _____ Ft^3 volume added for any of the above
f. How installed: Tremie ☒ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
b. ☐ 1/4 in. ☐ 3/8 in. ☒ 1/2. Bentonite pellets ☒
c. _____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
a. _____
b. Volume added _____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
a. CSSI COLORADO 20/40
b. Volume added _____ ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐ _____
10. Screen material: SCH 40 PVC
a. Screen type: Factory cut ☒ Continuous slot ☐ Other ☐ _____
b. Manufacturer: JOHNSON
c. Slot size: 0.010 in.
d. Slotted length: 5.__ ft.
10. Screen material: ~~None~~ ☐ Other ☐ _____

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: Bruce J. Siegmund
Firm: DAMSCHEN + ASSOC.

State of Montana
Department of Health
and Environmental Sciences

Route to: Solid Waste ☒ Haz. Waste ☐ SuperFund/CECRA ☐ Underground Tanks ☐ Other ☐ _____

MONITORING WELL DEVELOPMENT

Facility/Project Name	County Name	Well Name
UNIFIED DISPOSAL DIST. LF	BLAINE	MW-4

Facility License Number	County Code	MT Unique Well Number	DHES Well Number
222			

1. Can this well be purged dry? ☒ Yes ☐ No

2. Well development method
   - surged with bailer and bailed ☒
   - surged with bailer and pumped ☐
   - surged with block and bailed ☐
   - surged with block and pumped ☐
   - surged with block, bailed and pumped ☐
   - compressed air ☐
   - bailed only ☐
   - pumped only ☐
   - pumped slowly ☐
   - Other _____ ☐

3. Time spent developing well 50 min.

4. Depth of well (from top of casing) 118.8 ft.

5. Inside diameter of well 2.0 in.

6. Volume of water in filter pack and well casing ~5. gal.

7. Volume of water removed from well 5+. gal.

8. Volume of water added (if any) ____. gal.

9. Source of water added _____

10. Analysis performed on water added? ☒ Yes ☐ No
(If yes, attach results)

	Before Development	After Development
11. Depth to Water (from top of well casing)	a. 92.25 ft.	91.25 ft.
Date	b. 04/20/93 (mm dd yy)	04/20/93 (mm dd yy)
Time	c. 9:00 ☒ a.m. ☐ p.m.	11:00 ☒ a.m. ☐ p.m.
12. Sediment in well bottom	2.- inches	___. inches
13. Water clarity	Clear ☐ Turbid ☒ (Describe) GREY SILT	Clear ☐ Turbid ☒ (Describe) GREY SILT

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids	____. mg/l	4. mg/l
15. COD	____. mg/l	____. mg/l

16. Additional comments on development ~ AFTER DEVELOPMENT.

Temp = 51° F
SC = 4,600 umho
pH = 8.99 su

Well developed by: (Person's Name and Firm)

Name: BRUCE L. SIEGMUND

Firm: DAMSCHEN + ASSOC

I hereby certify that the above information is true and correct to the best of my knowledge

Signature: Bruce L. Siegmund

Print Initials: BLS

Firm: DAMSCHEN + ASSOC

Note: Shaded areas are for DHES use only. See instructions for more information including a list of county codes.

TEST BORING LOG

Project Name UNIFIED DISPOSAL
Location T32N, R18E, SW NW Sec.6
Location (N,S) _____ (E,W) _____
Surface Elevation 2593
Driller SHARP DRILLING, SIDNEY, MT.
Hole Dia. 4 3/4"

Project number 93-06
Well number UDD-14
Date(s) 4/17/93
Logged By B. SIEGMUND
Drill Method AIR ROTARY
Casing (type, depth) N/A

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2593		TOPSOIL, VERY DRY SANDY LOAM
5			
10	2583		POORLY SORTED, FINE TO MEDIUM GRAINED SAND WITH AMPLE SILT AND STREAKS OF FINE TO MEDIUM GRAVEL, SEVERAL GRAVEL BEDS < 0.25 FEET THICK AT 20 - 26 FEET, Qg
15			
20	2573		
25			
30	2563		
35			SILTY GRAY SHALE, IRON STAINS ON PARTINGS AT 45'-48', SHELL BED AT 48'
40	2553		
45			
50			

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TEST BORING LOG

Project Name UNIFIED DISPOSAL
Location T32N,R18E,SE NW SEC.6
Location (N,S) _____ (E,W) _____
Surface Elevation 2568.06
Driller SHARP DRILLING, SIDNEY,MT.
Hole Dia. 4 3/4"

Project number 93-06
Well number UDD-15/P-1/P-2
Date(s) 4/17/93
Logged By B. SIEGMUND
Drill Method AIR ROTARY
Casing (type, depth) 1.25"PVC,70'-80'

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION	WELL CONST. DETAILS
	2568		TOPSOIL, SANDY LOAM	
5			POORLY SORTED SILT, SAND AND GRAVEL, POSSIBLY SOME WASHED GLACIO-FLUVIAL SANDS IN PLACES, Qg	
10	2558			
15			MEDIUM BROWN CLAY AND SILT WITH SCATTERED POLISHED PEBBLES, Qg GROUND MORAINE, STICKY	
			BROWN CLAY, Klr	
20	2548		SILTY, LIGHT GRAY CLAY	
			VERY RESISTANT CARBONATE RICH SILTY SANDSTONE/ SANDY CARBONATE	
25			GRAY SILT WITH IRON NODULES	
			SILTY GRAY CLAY	
			VERY FINE GRAINED, SILTY GRAY SAND, SHELL BED AT 27.5'	
30	2538		VERY RESISTANT CARBONATE RICH SILTY SANDSTONE/ SANDY CARBONATE	
			GRAY-BROWN CLAY WITH IRON NODULES	
35				P-1
			GRAY-BROWN CLAY GRADING TO SILTY GRAY CLAY	P-2
40	2528			
45			FINE GRAINED GRAY SAND	
			SILTY GRAY CLAY	
			FINE GRAINED GRAY SAND	
50	2518		SILTY GRAY CLAY, SHELLS AT TOP OF INTERVAL	

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TEST BORING LOG

Project Name UNIFIED DISPOSAL

Project number 93-06

Well number UDD-15/P-1/P-2

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION	WELL CONST. DETAILS
	2518		SILTY GRAY CLAY GRADING TO RUSTY BROWN CLAY.	
55			SILTY, POORLY SORTED, FINE GRAINED GRAY SAND, DAMP	P-2
60	2508		SILTY BROWN SAND, MOIST	
			CARBONATE RICH GRAY SANDSTONE/SANDY CARBONATE	
65			SILTY GRAY SAND	
			INTERBEDDED SILTY SAND AND SILTY CLAY	
70	2498			
			GRAY-BROWN CLAY GRADING TO GRAY CLAY	P-1
75			SILTY GRAY SAND, MOIST	
			GRAY CLAY	
80	2488		HOLE COMPLETED AS PIEZOMETER NEST, P-1 COMPLETED AT 80', P-2 COMPLETED AT 70', DETAILS AS INDICATED, CONSTRUCTED OF 1.25" I.D. SCH. 80 PVC WITH HAND-CUT 0.025" SLOTS, FILTER PACK OF 12/20 CSSI COLORADO SAND, SEAL AND GROUT OF #8 GRANULAR BENTONITE, PROTECTIVE CASING OF 4" SCH. 40 PVC.	

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TEST BORING LOG

Project Name UNIFIED DISPOSAL
Location T32N,R18E,SW NW SEC.6
Location (N,S) _____ (E,W) _____
Surface Elevation 2589.06/COLLAR=2591.56
Driller SHARP DRILLING, SIDNEY,MT.
Hole Dia. 4 3/4"

Project number 93-06
Well number UDD-16/P-3
Date(s) 4/17/93
Logged By B. SIEGMUND
Drill Method AIR ROTARY
Casing (type, depth) 1.25"PVC,38'

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION	WELL CONST. DETAILS
	2589		TOPSOIL, SANDY LOAM	
5				
			SILT AND SAND, TAN TO BROWN, WITH STREAKS OF GRAVEL AS INDICATED, 10'-18' CONTAINS A GREATER PERCENTAGE OF GLACIOFLUVIAL SANDS.	
10	2579			
15				
20	2569		SILTY BROWN CLAY, SLIGHTLY STICKY	
			HEAVILY IRON STAINED SILT AND CLAY, SLIGHTLY STICKY	
25			SILTY, GRAY CLAY, DRY, SHELL BED AT 26'	
			OCHRE AND YELLOW LIMONITIC CLAY AND MAROON CLAY	
30	2559			
			SILTY GRAY CLAY, DRY, GRADING TO SANDY, BROWNISH-GRAY CLAY, POSSIBLY SOME THIN SAND BEDS, STICKY	
35				
40	2549		SILTY GRAY CLAY, DRY.	
			COMPLETED AS PIEZOMETER WITH 1.25" I.D. SCH. 80 PVC, HAND CUT 0.025" SLOTS, FILTER PACK=12/20 CSS, COLORADO SAND, GROUT AND SEAL #8 GRANULAR BENTONITE, AS INDICATED.	
45				
50	2518			

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TEST BORING LOG

Project Name UNIFIED DISPOSAL
Location T32N, R17E, SE NE Sec.1
Location (N,S)_____(E,W)_____
Surface Elevation 2601
Driller SHARP DRILLING, SIDNEY, MT.
Hole Dia. 4 3/4"

Project number 93-06
Well number UDD-17
Date(s) 4/18/93
Logged By B. SIEGMUND
Drill Method AIR ROTARY
Casing (type, depth) N/A

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	260		
5			BROWNISH-TAN SAND WITH SCATTERED GRAVEL
10	259		BROWN SILTY CLAY
			VERY FINE GRAINED TO FINE GRAINED YELLOWISH-BROWN SAND
15			MEDIUM TO COARSE GRAVEL
20	258		FINE YELLOWISH-BROWN SAND WITH CLAY BEDS AND GRAVEL STREAKS AS INDICATED.
25			
30	257		TOP OF Klr
			MAROON CLAY
35			SILTY GRAY CLAY
			VERY FINE GRAINED, LIMONITIC SAND
			VERY FINE GRAINED GRAY SAND
40	256		SILTY GRAY CLAY
			VERY FINE GRAINED GRAY SAND
			IRON STAINED CLAYEY SILT AND SAND
45			VERY DARK GRAY CLAY GRADING TO LIGHT GRAY CLAY AT 45'
	255		

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TEST BORING LOG

Project Name UNIFIED DISPOSAL

Project number 93-06
Well number UDD-17

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
50			LIGHT GRAY SILTY CLAY VERY FINE GRAINED GRAY SAND GRAY CLAY
55			CARBONATE RICH SANDSTONE/SANDY CARBONATE
			INTERBEDDED GRAY CLAY AND SILTY GRAY SAND
60	254		

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TEST BORING LOG

Project Name UNIFIED DISPOSAL
Location T32N, R18E, SE NW Sec.6
Location (N,S) 180N (E,W) 2920E
Surface Elevation 2606.69
Driller SHARP DRILLING, SIDNEY, MT.
Hole Dia. 4 3/4"

Project number 93-06
Well number UDD-18/MW-6
Date(s) 4/18/93
Logged By B. SIEGMUND
Drill Method AIR ROTARY
Casing (type, depth) 2" PVC, 105'

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2606.7		TOPSOIL, SANDY LOAM
5			
10	2596.7		YELLOWISH-BROWN SILT AND SAND
15			
20	2586.7		BROWN, SILTY CLAY, SLIGHTLY SILTY
25			
30	2576.7		BROWNISH-GRAY SILTY CLAY GRADING TO LIGHT GRAY SILTY CLAY AT ~30'
35			
			VERY FINE GRAINED TO FINE GRAINED GRAY SAND
40	2566.7		SILTY, IRON STAINED SILTY SAND GRADING TO BROWNISH-GRAY SAND, ALL FINE GRAINED AND POORLY SORTED.
45			SILTY GRAY CLAY
50	2556.7		

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TEST BORING LOG

Project Name UNIFIED DISPOSAL

Project number 93-06

Well number UDD-18/MW-6

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
	2556.7		
55			SILTY GRAY CLAY
60	2546.7		
65			
70	2536.7		GRAY-BROWN SILTY, SAND CLAY
75			SILTY GRAY CLAY
			GRAY-BROWN CLAY
80	2526.7		SILTY GRAY CLAY
			GRAY SILTY SAND INTERBEDDED WITH CARBON RICH MAROON SAND, FINE GRAINED.
85			INTERBEDDED GRAY AND BROWN SILTY CLAY
90	2516.7		SILTY, FINE GRAINED GRAY SAND
95			INTERBEDDED GRAY SAND AND CLAYEY SILT
100	2506.7		SANDY GRAY CLAY AND FINE GRAY SAND, POOR RETURN,
105			COMPLETED AS MONITORING WELL, SEE DHES CONSTRUCTION FORMS.

Damschen & Associates, Inc.
CONSULTING ENGINEERS
•2030 11th Ave., Suite 11•
•HELENA, MONTANA•

State of Montana
Department of Health
and Environmental Sciences

Route to: Solid Waste ☒ Haz. Waste ☐
Underground Tanks ☐ Other ☐ _____

MONITORING WELL CONSTRUCTION

Facility/Project Name: UNIFIED DISPOSAL DIST. LF

Facility License: 222

Type of Well: Water Table Observation Well ☐ Piezometer ☐

Distance Well Is From Waste/Source Boundary: 50 ft

Is Well a Point of Standards Application? ☐ Yes ☐ No

Local Grid Location of Well: _____ ft ☐ N ☐ S _____ ft ☐ E ☐ W

Grid Origin Location: Lat. ___ ___ ___ Long. ___ ___ ___ or

St. Plane _____ ft N _____ ft S

Section Location of Waste/Source ☐ E ☐ W

Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known

Well Name: MW-6

MT Unique Well Number | DHES Well Name

Date Well Installed: 04/18/93 (mm dd yy)

Well Installed By: (Person's Name and Firm) JOHN SHARP, SHARP DRILLING
BRUCE SIEGMUND, DAMSCHEN + ASSOC.

A. Protective pipe, top elevation 2610.09 ft. MSL

B. Well casing, top elevation 2609.88 ft. MSL

C. Land Surface elevation 2606.48 ft. MSL

D. Surface seal, bottom ____.__ ft. MSL or 3.__ ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ GW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☐ Hollow Stem Auger ☐ Other ☐ _____

15. Drilling fluid used: Water ☐ Air ☐ Drilling Mud ☐ None ☐

16. Drilling additives used? ☐ Yes ☐ No

Describe _____

17. Source of water: _____

E. Bentonite seal, top ____.__ ft. MSL or 98.__ ft.

F. Fine sand, top ____.__ ft. MSL or N/A.__ ft.

G. Filter pack, top ____.__ ft. MSL or 99.0 ft.

H. Screen joint, top ____.__ ft. MSL or 99.5 ft.

I. Well bottom ____.__ ft. MSL or 104.5 ft.

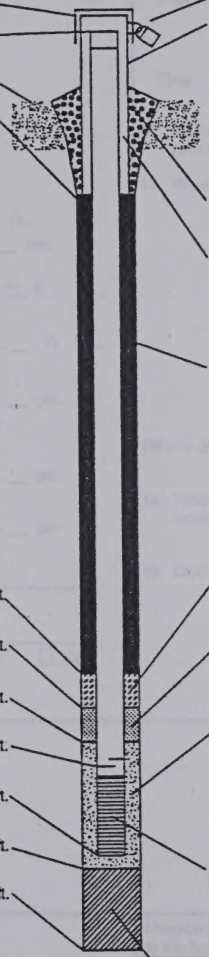
J. Filter pack, bottom ____.__ ft. MSL or 104.5 ft.

K. Borehole bottom ____.__ ft. MSL or 105.__ ft.

L. Borehole, diameter ____.__ in.

M. O.D. well casing ____.__ in.

N. I.D. well casing ____.__ in.



1. Cap and lock? ☒ Yes ☐ No
2. Protective cover pipe:
   a. Inside diameter: 4.__ in.
   b. Length: 5.__ ft.
   c. Material: Steel ☒ Other ☐ _____
   d. Additional protection? – ☐ Yes ☐
   If yes, describe: _____
3. Surface seal: Bentonite ☐ Concrete ☒ Other ☐ _____
4. Material between well casing and protective pipe: Bentonite ☒ Annular space seal ☐ Other ☐ _____
5. Annular space seal: a. Granular bentonite ☒
   b. ____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐
   c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐
   d. ____ % bentonite . . . . . Bentonite cement grout ☐
   e. _____ Ft^3 volume added for any of the above
   f. How installed: Tremie ☒ Tremie pumped ☐ Gravity ☒
6. Bentonite seal: a. Bentonite granules ☐
   b. ☐ 1/4 in. ☐ 3/8 in. ☒ 1/2. Bentonite pellets ☒
   c. _____ Other ☐
7. Fine sand material: Manufacturer, product name & mesh size
   a. N/A
   b. Volume added _____ ft^3
8. Filter pack material: Manufacturer, product name & mesh size
   a. CSSI COLORADO 20/40
   b. Volume added (ft^3
9. Well casing: Flush threaded PVC schedule 40 ☒ Flush threaded PVC schedule 80 ☐ Other ☐ _____
10. Screen material: SCH 40 PVC
    a. Screen type: Factory cut ☒ Continuous slot ☐ Other ☐ _____
    b. Manufacturer: JOHNSON
    c. Slot size: 0.010 in.
    d. Slotted length: 5.__ ft.
    10. Screen material: ~~None~~ ☐ Other ☐ _____

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm
Bruce J. Siegmund	DAMSCHEN + ASSOC.

State of Montana
Department of Health
and Environmental Sciences

Route to: Solid Waste ☒ Haz. Waste ☐ SuperFund/CECRA ☐ Underground Tanks ☐ Other ☐ _____

MONITORING WELL DEVELOPMENT

Facility/Project Name	County Name	Well Name
UNIFIED DISPOSAL DIST. LF	BLAINE	MW-6

Facility License Number	County Code	MT Unique Well Number	DHES Well Number
222			

1. Can this well be purged dry? ☐ Yes ☐ No

2. Well development method
   - surged with bailer and bailed ☐
   - surged with bailer and pumped ☐
   - surged with block and bailed ☐
   - surged with block and pumped ☐
   - surged with block, bailed and pumped ☐
   - compressed air ☐
   - bailed only ☐
   - pumped only ☐
   - pumped slowly ☐
   - Other _____ ☐

3. Time spent developing well 50 min.

4. Depth of well (from top of casing) 108.4 ft.

5. Inside diameter of well 2. in.

6. Volume of water in filter pack and well casing ~3. gal. 17.15

7. Volume of water removed from well ~5. gal.

8. Volume of water added (if any) ____. gal.

9. Source of water added _____

10. Analysis performed on water added? ☒ Yes ☐ No
(If yes, attach results)

	Before Development	After Development
11. Depth to Water (from top of well casing)	a. 92.25 ft.	91.25 ft. (MAY STILL BE RECOV. FROM @ THIS TIME)
Date	b. 04/19/93 (mm dd yy)	04/19/93 (mm dd yy)
Time	c. 11:00 ☒ a.m. ☐ p.m.	12:00 ☐ a.m. ☐ p.m.
12. Sediment in well bottom	1.__ inches	___. inches
13. Water clarity	Clear ☐ Turbid ☒ (Describe) LIGHT GY	Clear ☐ Turbid ☐ (Describe) LIGHT GY

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids	____. mg/l	33. mg/l
15. COD	____. mg/l	____. mg/l

16. Additional comments on development

Temp = 51.8° F
S.C. = 4730 µmho
pH = 8.64

Well developed by: (Person's Name and Firm)

Name: BRUCE SIEGMUND

Firm: DAMSCHEN + ASSOC.

I hereby certify that the above information is true and correct to the best of my knowledge

Signature: Bruce L. Siegmund

Print Initials: BLS

Firm: DAMSCHEN + ASSOC.

Note: Shaded areas are for DHES use only. See instructions for more information including a list of county codes.

TEST BORING LOG

Project Name UNIFIED DISPOSAL
Location T32N, R18E, NW SE Sec.6
Location (N,S) _____ (E,W) _____
Surface Elevation 2604.48/COLLAR=2605.19
Driller SHARP DRILLING, SIDNEY, MT.
Hole Dia. 4 3/4"

Project number 93-06
Well number UDD-19/P-4
Date(s) 4/18/93
Logged By B. SIEGMUND
Drill Method AIR ROTARY
Casing (type, depth) 1.25"PVC/15'

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION	WELL CONST. DETAILS
			FINE GRAINED BROWN TO TAN SAND	
5	2599.5			
10	2594.5		COARSE SAND AND GRAVEL, POORLY SORTED	CAVED
15	2589.5		TOP OF Klr SILTY GRAY CLAY	
20				

COMPLETED AS PIEZOMETER, HOLE CAVED SEVERAL TIMES DURING INSTALLATION, FINALLY INSTALLED AT ~10' DEPTH, COMPLETED AS INDICATED WITH 1.25" I.D. SCH. 80 PVC, HAND CUT 0.025" SLOTS, FILTER PACK OF 12/20 CSSI COLORADO SAND, SEALED AND GROUTED WITH #8 GRANULAR BENTONITE.

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APPENDIX C. LOGS OF TEST PITS

TEST PIT LOG

Project Name: UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.): T32N, R18E, NE, SW, 6
Grid (N,S): _____ (E,W): _____
Surface Elevation: 2610

Project number: 93-06
Pit number: TP-34
Date(s): 7/26/93
Logged By: D. PAYNE
Method: BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			LIGHT BROWN SANDY LOAM
			MEDIUM GRAINED SAND
5			SAND WITH MINOR (<10%) GRAVEL AND SMALL COBBLES POORLY SORTED GLACIAL TILL
			SAND WITH MINOR COAL CLASTS (<5%) AND CLAY LENSES APPARENT SLOPE TO THE SOUTH
10			POORLY SORTED SAND GLACIAL TILL BOULDER (3' LENGTH) IN PIT WALL
			RED STAINED CLAY WITH MINOR (<5%) COHERENT COAL CLASTS (2-4"), HARD, COMPACT, Kjr
15			
20			

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TEST PIT LOG

Project Name: [illegible]
(TWP, RNG, Sec): [illegible]
Coord. (N,E): _____ (X,Y)
Surface Elevation: [illegible]

Project number: [illegible]
Pit number: [illegible]
Date(s): [illegible]
Logged By: [illegible]
Method: [illegible]

DEPTH (FEET)	DEPTH (METERS)	MATERIALS DESCRIPTION	PROFILE CHARACTER
		LIGHT BROWN SANDY LOAM	
		MEDIUM COARSE SAND	
		SAND WITH MINOR LIGHT GRAVEL AND SMALL COBBLES FOUND BEARING TILL	
		SAND W TH MINOR COAL SLIGHTS (1-5%) AND COAL LENSES APPARENT CLOSE TO THE SOUTH	
		POORLY SORTED SAND BEARING TILL — BOULDER (8 LENGTH) IN PIT WALL	
		RED STAINED COAL WITH MINOR (1-5%) CONTAINED COAL SLAGTS 1 1/2 - 2 1/2 MM COMPACT, SILT	

Dawnlen & Associates, Inc.
[illegible]

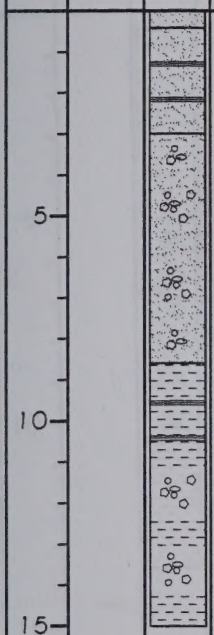
PAGE 1 OF 1

TEST PIT LOG

Project Name: UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.): T32N, R18E, NE, SW, 6
Grid (N,S): _____ (E,W): _____
Surface Elevation: 2610

Project number: 93-06
Pit number: TP-35
Date(s): 7/26/93
Logged By: D. PAYNE
Method: BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			SANDY LOAM
			MEDIUM SAND, MINOR COAL STRINGERS THAT DIP TO THE SOUTH
			GRAVELS, COBBLES, PEBBLES, UNSORTED. GLACIAL TILL
5			
10			GRAY CLAY WITH MINOR COAL LENSES AND CLASTS (<3") AND GRAVEL TO PEBBLES, SUBROUNDED.
15			
20			



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TEST PIT LOG

Project Name: UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.): T32N, R18E, NE, SW, 6
Grid (N,S) _____ (E,W) _____
Surface Elevation: 2610

Project number: 93-06
Pit number: TP-36
Date(s): 7/26/93
Logged By: D. PAYNE
Method: BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			SILT
			MEDIUM SAND
5			SAND, GRAVELS, COBBLES, SUBROUNDED TO ROUNDED GLACIAL TILL
10			GRAY CLAY WITH MINOR COAL CLASTS TO PEBBLES, ON TOP MOIST TO WET, Klr
15			
20			

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TEST PIT LOG

Project Name: UNDERED DISPOSAL PIT
(TWP, RNG, Sec.) TWP 01N2 RNG 3W
Grid (N/S) _____ (E/W) _____
Surface Elevation _____ (MSL)

Project number 93-08
Pit number 10-5
Date(s) 12/01/93
Logged By D. Cline
Method: BACKHOE

Depth (Feet)	Water Level (Date)	Sample No.	MATERIALS DESCRIPTION
0			SILT LOOSE, BROWN SAND, GRAVEL, COBBLES WEATHERED TO BROWN GLACIAL TILL
10			GRAY SILT WITH MEDIUM SAND, QUARTZ TO FEMALS OR TOP MOISTY TO WET, SILT
15			
20			

TEST PIT LOG

Project Name UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.) T32N, R18E, NE, SW, 6
Grid (N,S) _____ (E,W) _____
Surface Elevation 2610

Project number 93-06
Pit number TP-37
Date(s) 7/26/93
Logged By D. PAYNE
Method BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			SANDY LOAM
			GRAVELLY SAND
5			SAND WITH COBBLES TO BOULDERS, ROUNDED TO SUBROUNDED
			GRAVELLY SAND
10			
			GRAY CLAY, PLASTIC, MOIST TO WET, Kjr
15			SHALE TO CLAY, DIPS TO SOUTH, Kjr
20			

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TEST PIT LOG

Project Name: UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.): T32N, R18E, SEC. 6
Grid (N,S) _____ (E,W) _____
Surface Elevation: 2592

Project number: 93-06
Well number: TP-E1
Date(s): 4/13/93
Logged By: B.L.S.
Drill Method: BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			DARK BROWN SANDY LOAM
			LIMEY HARDPAN IN POORLY SORTED SAND AND GRAVEL
5			GLACIAL DRIFT, POORLY SORTED SAND AND GRAVEL
10			COARSE TO MEDIUM SAND WITH MINOR GRAVEL PROBABLY CRETACEOUS JUDITH RIVER Fm. (?)
15			SAND GRADES TO RUSTY SILT AND SILT STONE WITH AMPLE ORGANIC MATTER.
20			DRY
25			
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TEST PIT LOG

Project Name [illegible]
(TWP, RNG, Sec [illegible])
Cnd (N,S) _____ (E,W) _____
Surface Elevation _____ [illegible]

Project number 03-06
Well number 77-61
Date(s) [illegible]
Logged By [illegible]
Drill Method [illegible]

DEPTH (FEET)	VEN (FEET)	ORGANIC TOP	MATERIALS DESCRIPTION
0			DARK BROWN SANDY LOAM
5			LIGHT MATERIAL IS MOSTLY SORTED SAND AND GRAVEL
			BLACKISH DRIFT, MOSTLY SORTED SAND AND GRAVEL
10			COARSER TO MEDIUM SAND WITH MINOR GRAVEL, PROBABLY CONTAMINATED WITH SILTY MATERIAL (?)
15			SAND BEGINS TO MOSTLY SILT AND SILT STONE WITH ANGULAR GRAVEL & MAT MIX
20			DRY
25			
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TEST PIT LOG

Project Name UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.) T32N.R18E.SEC.6
Grid (N,S) _____ (E,W) _____
Surface Elevation 2593

Project number 93-06
Well number TP-E2
Date(s) 4/13/93
Logged By B.L.S.
Drill Method BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			TOPSOIL, SANDY, COBBLY, LOAM
			LIMEY HARDPAN
5			
10			POORLY SORTED GLCIAL DRIFT, LIGHT BROWN, SILT TO COBBLE SIZE, LOWEST PART OF PIT IS CLOSE TO Kjr, AS EVIDENCED BY RUSTY SILTSTONE CLASTS.
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TEST PIT LOG

Project Name UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.) T32N,R18E,SEC.6
Grid (N,S) _____ (E,W) _____
Surface Elevation 2575

Project number 93-06
Well number TP-E3
Date(s) 4/13/93
Logged By B.L.S.
Drill Method BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			MEDIUM BROWN SANDY LOAM
5			LIMEY HARDPAN
10			SILTY SAND, LIGHT TAN-GRAY, POORLY SORTED WITH MINOR GRAVEL, APPEARS GLACIAL IN ORIGIN
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TEST PIT LOG

Project Name UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.) T32N,R18E,SEC.6
Grid (N,S) _____ (E,W) _____
Surface Elevation 259-

Project number 93-06
Well number TP-E4
Date(s) 4/13/93
Logged By B.L.S.
Drill Method BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			MEDIUM BROWN GRAVELLY SANDY LOAM
5			LIGHT GRAY LIMEY HARDPAN
10			TAN TO GRAYISH TAN GLACIAL DRIFT, COBBLE TO SILT SIZED CLASTS, MOSTLY MEDIUM SAND
15			GRADES TO PEBBLES AND SAND IN SILTY CLAY MATRIX, MUCH FINER AND MORE COHESIVE THAN OVERLYING MATERIAL, THIS MAY BE GROUND MORAINE
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TEST PIT LOG

Project Name: UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.): T32N, R18E, SEC. 6
Grid (N,S) _____ (E,W) _____
Surface Elevation: 2591

Project number: 93-06
Well number: TP-E5
Date(s): 4/13/93
Logged By: B.L.S.
Drill Method: BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			LIGHT TO MEDIUM BROWN SANDY LOAM
5			LIGHT GRAY, LIMEY HARDPAN
10			GRAYISH BROWN, SILTY, COBBLY SAND, APPEARS TO BE GLACIAL DRIFT, POORLY SORTED, LOWEST PORTION CONTAINS CLASTS OF IRON STAINED ORGANIC MATERIAL
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TEST PIT LOG

Project Name UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.) T32N,R18E,SEC.6
Grid (N,S) _____ (E,W) _____
Surface Elevation 2593

Project number 93-06
Well number TP-E6
Date(s) 4/13/93
Logged By B.L.S.
Drill Method BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			LIGHT BROWN SANDY HARDPAN
5			
10			GRAYISH TAN SAND AND SILT WITH SCATTERED COBBLES AND PEBBLES, MET REFUSAL AT 13.5 ON IGNEOUS BOULDER
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TEST PIT LOG

Project Name: UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.): T32N.R18E.SEC.6
Grid (N,S): _____ (E,W): _____
Surface Elevation: 2577

Project number: 93-06
Well number: TP-E7
Date(s): 4/13/93
Logged By: B.L.S.
Drill Method: BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			LIGHT REDDISH BROWN SANDY LOAM
			GRAVELLY, SANDY, LIMEY LIGHT GRAY HARDPAN
5			
10			VARIABLY SORTED GLACIAL DRIFT, SCATTERED POCKETS OF VERY CLAY RICH MATERIAL AND VERY SANDY MATERIAL THAT APPEARS TO BE CRETACEOUS SANDSTONE AND SHALE CLASTS INCORPORATED INTO DRIFT, MATRIX MATERIAL IS GENERALLY SANDY
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TEST PIT LOG

Project Name UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.) T32N,R18E,SEC.6
Grid (N,S) _____ (E,W) _____
Surface Elevation 2591

Project number 93-06
Well number TP-E8
Date(s) 4/13/93
Logged By B.L.S.
Drill Method BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			LIGHT TAN SANDY LOAM
			SANDY LIMEY HARDPAN
5			GLACIAL DRIFT, SOME WELL WASHED SANDS AT 3' TO 4', REMAINDER IS GENERALLY POORLY SORTED SILT TO COBBLE SIZED MATERIAL, A FEW CLASTS OF CRETACEOUS SEDIMENTS NOTED, MOSTLY CARBON RICH SILT AND CLAY
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TEST PIT LOG

Project Name UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.) T32N,R18E,SEC.6
Grid (N,S) _____ (E,W) _____
Surface Elevation 2597

Project number 93-06
Well number TP-E9
Date(s) 4/13/93
Logged By B.L.S.
Drill Method BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			SANDY, GRAVELLY LOAM
			GRAVELLY, LIMEY HARDPAN
5			
10			POORLY SORTED GLACIAL DRIFT, PREDOMINANTLY SAND AND SILT
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TEST PIT LOG

Project Name UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.) T32N,R18E,SEC.6
Grid (N,S) _____ (E,W) _____
Surface Elevation 2584

Project number 93-06
Well number TP-E10
Date(s) 4/13/93
Logged By B.L.S.
Drill Method BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			DARK BROWN SANDY, GRAVELLY LOAM
			LIGHT GRAY LIMEY, GRAVELLY HARDPAN
5			
			VARIABLY SORTED SILT, SAND AND GRAVEL
10			
15			
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TEST PIT LOG

Project Name UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.) T32N.R18E.SEC.6
Grid (N,S) _____ (E,W) _____
Surface Elevation 2606

Project number 93-06
Well number TP-E11
Date(s) 4/13/93
Logged By B.L.S.
Drill Method BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			MEDIUM BROWN SANDY LOAM
5			LIGHT GRAY, COBBLY, SANDY HARDPAN
			GLACIOFLUVIAL SAND
10			GLACIAL DRIFT, POORLY SORTED, COBBLE TO SILT SIZED, LOWER MOST FOOT OR TWO APPEARS TO BE GROUND MORAINE COMPRISING POLISHED PEBBLES AND GRAVEL IN A VERY FINE GRAINED MATRIX
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TEST PIT LOG

Project Name: UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.): T32N,R18E,SEC.6
Grid (N,S): ____ (E,W): ____
Surface Elevation: 2604

Project number: 93-06
Well number: TP-E12
Date(s): 4/13/93
Logged By: B.L.S.
Drill Method: BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			DARK BROWN SANDY LOAM
5			LIGHT GRAY LIMEY HARDPAN, SILT TO COBBLES IN SIZE
10			MEDIUM BROWN TO TAN SILT AND SAND WITH MINOR GRAVEL, ORGANIC BLEBS THROUGHOUT
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TEST PIT LOG

Project Name UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.) T32N.R18E.SEC.6
Grid (N,S) _____ (E,W) _____
Surface Elevation 2609

Project number 93-06
Well number TP-E13
Date(s) 4/13/93
Logged By B.L.S.
Drill Method BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			LIGHT BROWN SANDY LOAM (TO 3' IN PLACES)
			SILTY, GRAVELLY, LIMEY HARDPAN
5			SILTY, GRAVELLY SAND, POORLY SORTED
10			
15			GROUND MORAINE, SILT AND CLAY MATRIX WITH EMBEDDED PEBBLES
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TEST PIT LOG

Project Name UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.) T32N, R18E, SEC. 6
Grid (N,S) _____ (E,W) _____
Surface Elevation 2605

Project number 93-06
Well number TP-E14
Date(s) 4/13/93
Logged By B.L.S.
Drill Method BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			MEDIUM TO LIGHT BROWN SANDY LOAM
5			LIGHT GRAY SILT, SAND AND GRAVEL, LIMEY HARDPAN
10			VARIABLY SORTED SILT, SAND AND GRAVEL, GLACIAL DRIFT
15			
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TEST PIT LOG

Project Name UNIFIED DISPOSAL DIST.
(TWP, RNG, Sec.) T32N, R18E, SEC. 6
Grid (N,S) _____ (E,W) _____
Surface Elevation 2604

Project number 93-06
Well number TP-E15
Date(s) 4/13/93
Logged By B.L.S.
Drill Method BACKHOE

DEPTH (FEET)	ELEV. (FEET)	GRAPHIC LOG	MATERIALS DESCRIPTION
			DARK TO MEDIUM BROWN SANDY LOAM
5			LIGHT GRAY LIMEY HARDPAN
10			VARIABLY SORTED SILT TO COBBLE SIZED SEDIMENTS, GLACIAL DRIFT
15			
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APPENDIX D. RESULTS AND ANALYSIS OF SLUG TESTS AND PERMEAMETER TEST

Well No. MW-3

SWL/BAILER 44.59 SWL 43.08

Time	SWL	h	h/ho
10	44.39	1.31	0.868
50	44.31	1.23	0.815
80	44.24	1.16	0.768
120	44.2	1.12	0.742
180	44.15	1.07	0.709
360	44.07	0.99	0.656
430	44.01	0.93	0.616
600	43.91	0.83	0.55
660	43.88	0.8	0.53
720	43.85	0.77	0.51
780	43.82	0.74	0.49
840	43.8	0.72	0.477
960	43.75	0.67	0.444
1020	43.72	0.64	0.424
1080	43.7	0.62	0.411
1140	43.68	0.6	0.397
1200	43.66	0.58	0.384
1260	43.64	0.56	0.371
1320	43.63	0.55	0.364
1380	43.62	0.54	0.358
1440	43.6	0.52	0.344
1500	43.58	0.5	0.331
1620	43.55	0.47	0.311
1740	43.53	0.45	0.298
1860	43.51	0.43	0.285
1980	43.49	0.41	0.272
2280	43.44	0.36	0.238
2460	43.42	0.34	0.225
2700	43.39	0.31	0.205
2940	43.36	0.28	0.185
3600	43.3	0.22	0.146
7050	43.18	0.1	0.066
9960	43.14	0.06	0.04
14160	43.12	0.04	0.026
0	43.1	1.51	

10	0.86755
50	0.81457
80	0.768212
120	0.741722
180	0.708609
360	0.655629
430	0.615894
600	0.549669
660	0.529801
720	0.509934
780	0.490066
840	0.476821
960	0.443709
1020	0.423841
1080	0.410596
1140	0.397351
1200	0.384106
1260	0.370861
1320	0.364238
1380	0.357616
1440	0.344371
1500	0.331126
1620	0.311258
1740	0.298013
1860	0.284768
1980	0.271523
2280	0.238411
2460	0.225166
2700	0.205298
2940	0.18543
3600	0.145695
7050	0.066225
9960	0.039735
14160	0.02649

Slug-in testMW-3

Hole diamete0.395833 feet (r)

Well diamete0.083333 feet (R)

SWL = 42.36 feet

Start time = PM

ho = 1.51

L = 5

0.37 = 1035

K(ft/day) = 321.317

K(cm/sec) 0.113425

Well No. MW-4

SWL/BAILER 92.19 SWL 90.68

Time	SWL	h	h/ho		
30	93.02	2.34	1.5497	30	1.549669
60	92.9	2.22	1.4702	60	1.470199
120	92.6	1.92	1.2715	120	1.271523
180	92.03	1.35	0.894	180	0.89404
240	92.02	1.34	0.8874	240	0.887417
300	92.01	1.33	0.8808	300	0.880795
360	92	1.32	0.8742	360	0.874172
420	91.99	1.31	0.8675	420	0.86755
480	91.98	1.3	0.8609	480	0.860927
540	91.97	1.29	0.8543	540	0.854305
600	91.96	1.28	0.8477	600	0.847682
780	91.96	1.28	0.8477	780	0.847682
1020	91.95	1.27	0.8411	1020	0.84106
1140	91.94	1.26	0.8344	1140	0.834437
1380	91.93	1.25	0.8278	1380	0.827815
2040	91.91	1.23	0.8146	2040	0.81457
2400	91.9	1.22	0.8079	2400	0.807947
5580	91.84	1.16	0.7682	5580	0.768212
9600	91.77	1.09	0.7219	9600	0.721854
79200	91.19	0.51	0.3377	79200	0.337748
0		1.51	1		

Slug-in test MW-4

Hole diameter 0.39583333 feet (r)

Well diameter 0.08333333 feet (R)

SWL = 42.36 feet

Start time = PM

ho = 1.51

L = 5

0.37 = 15600

K(ft/day) = 21.31815

K(cm/sec) 0.007525

Well No. MW-5

SWL/BAILER	24.72		23.21		
Time	SWL	h	h/ho		
30	24.6	1.39	0.921	30	0.92053
50	24.5	1.29	0.854	50	0.854305
60	24.48	1.27	0.841	60	0.84106
120	24.38	1.17	0.775	120	0.774834
140	24.31	1.1	0.728	140	0.728477
150	24.27	1.06	0.702	150	0.701987
180	24.25	1.04	0.689	180	0.688742
210	24.21	1	0.662	210	0.662252
240	24.18	0.97	0.642	240	0.642384
300	24.09	0.88	0.583	300	0.582781
420	24	0.79	0.523	420	0.523179
480	23.94	0.73	0.483	480	0.483444
540	23.9	0.69	0.457	540	0.456954
600	23.86	0.65	0.43	600	0.430464
720	23.8	0.59	0.391	720	0.390728
780	23.77	0.56	0.371	780	0.370861
840	23.75	0.54	0.358	840	0.357616
900	23.73	0.52	0.344	900	0.344371
1800	23.53	0.32	0.212	1800	0.211921
2100	23.47	0.26	0.172	2100	0.172185
2460	23.43	0.22	0.146	2460	0.145695
2700	23.4	0.19	0.126	2700	0.125828
3000	23.37	0.16	0.106	3000	0.10596
3300	23.36	0.15	0.099	3300	0.099338
3600	23.34	0.13	0.086	3600	0.086093
6000	23.31	0.1	0.066	6000	0.066225
89100	23.23	0.02	0.013	89100	0.013245
0		1.51	1		

Slug-in test MW-5

Hole diameter 0.395833 feet (r)

Well diameter 0.083333 feet (R)

SWL = 42.36 feet

Start time = PM

ho = 1.51

L = 5

0.37 = 885

K(ft/day) = 375.7776

K(cm/sec) 0.132649

Well No. MW-6

SWL/BAILER 90.31 SWL 88.8

Time	SWL	h	h/ho		
30	89.78	0.98	0.649007	30	0.649007
70	89.68	0.88	0.582781	70	0.582781
90	89.67	0.87	0.576159	90	0.576159
120	89.65	0.85	0.562914	120	0.562914
180	89.64	0.84	0.556291	180	0.556291
240	89.62	0.82	0.543046	240	0.543046
300	89.61	0.81	0.536424	300	0.536424
360	89.6	0.8	0.529801	360	0.529801
420	89.58	0.78	0.516556	420	0.516556
480	89.57	0.77	0.509934	480	0.509934
540	89.56	0.76	0.503311	540	0.503311
600	89.55	0.75	0.496689	600	0.496689
720	89.52	0.72	0.476821	720	0.476821
810	89.51	0.71	0.470199	810	0.470199
840	89.5	0.7	0.463576	840	0.463576
900	89.49	0.69	0.456954	900	0.456954
960	89.48	0.68	0.450331	960	0.450331
1020	89.47	0.67	0.443709	1020	0.443709
1080	89.46	0.66	0.437086	1080	0.437086
1770	89.35	0.55	0.364238	1770	0.364238
2400	89.28	0.48	0.317881	2400	0.317881
2700	89.24	0.44	0.291391	2700	0.291391
3480	89.17	0.37	0.245033	3480	0.245033
3900	89.14	0.34	0.225166	3900	0.225166
4680	89.08	0.28	0.18543	4680	0.18543
7020	88.97	0.17	0.112583	7020	0.112583
8160	88.93	0.13	0.086093	8160	0.086093
13800	88.86	0.06	0.039735	13800	0.039735
0		2.81			

Slug-in test MW-6

Hole diameter 0.395833 feet (r)

Well diameter 0.083333 feet (R)

SWL = 42.36 feet

Start time = PM

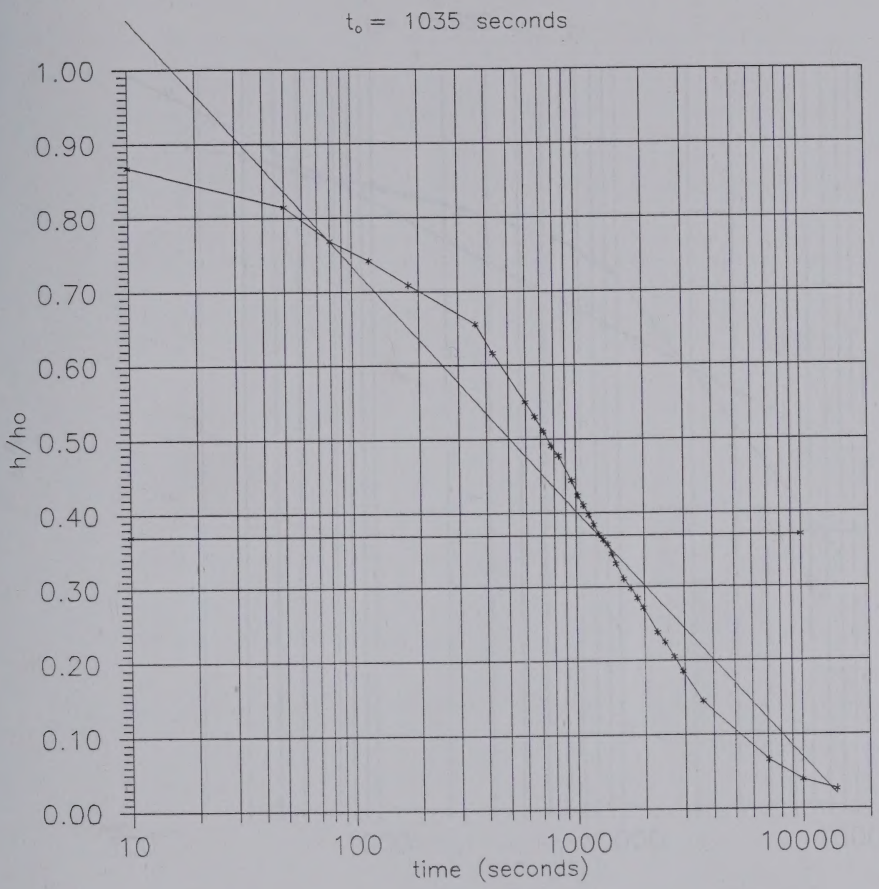
ho = 2.81

L = 5

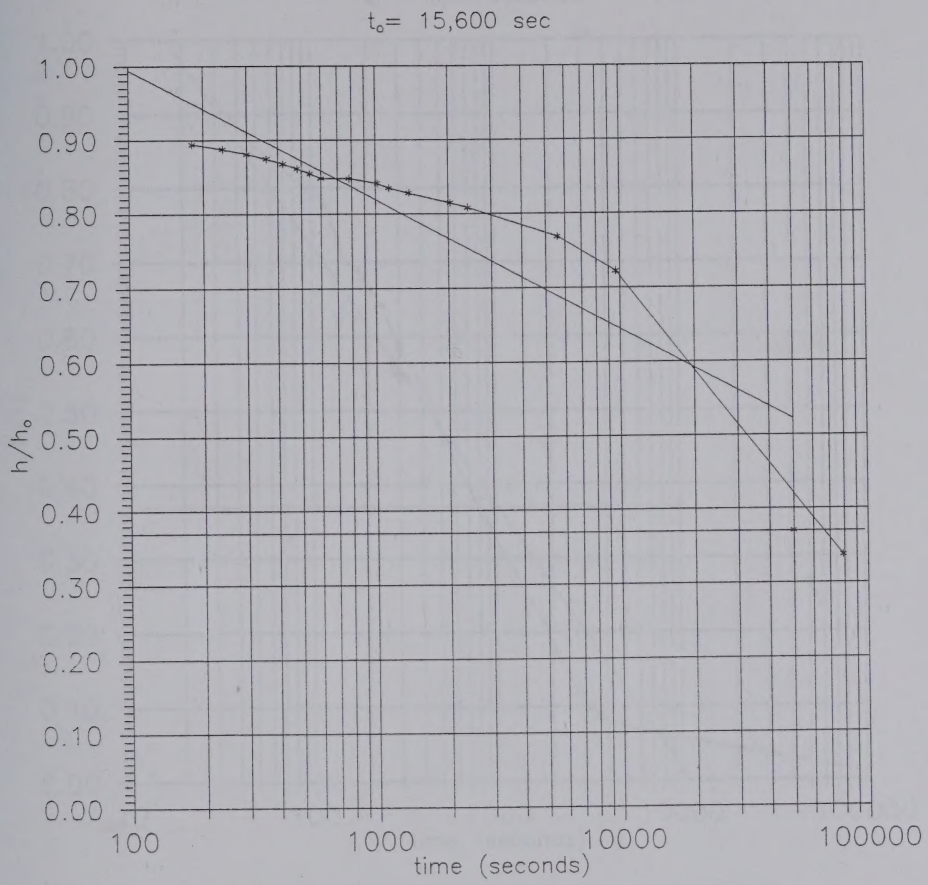
0.37 = 1075

K(ft/day) = 309.3611

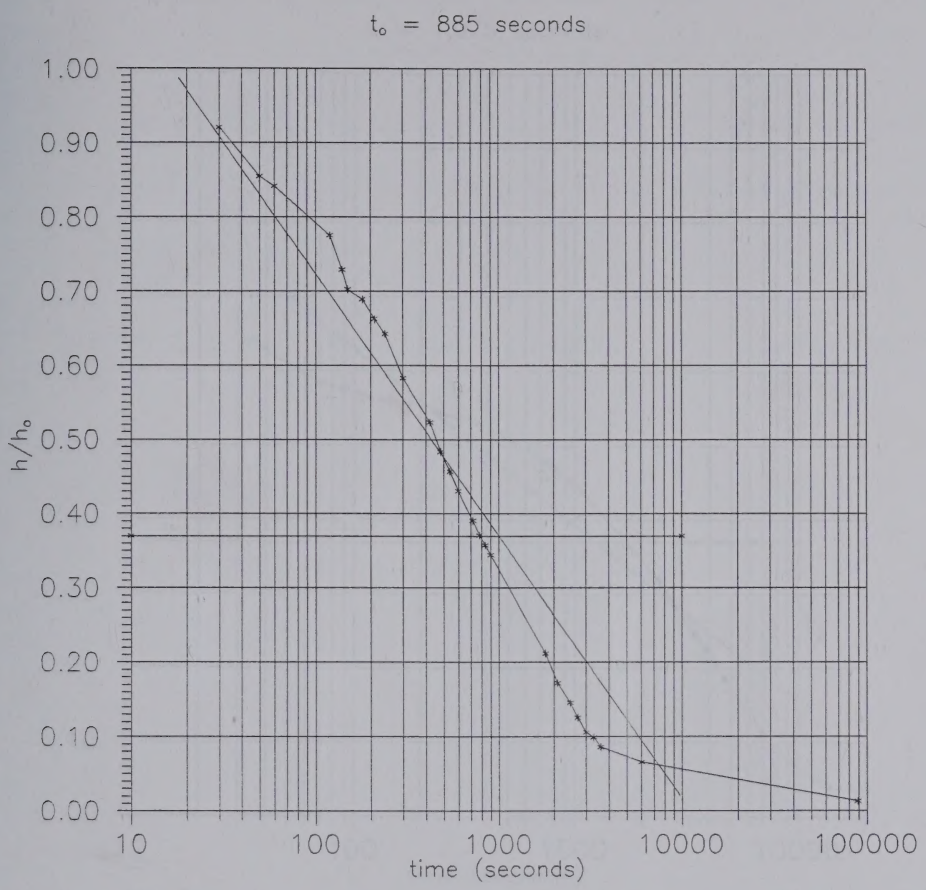
K(cm/sec) 0.109204



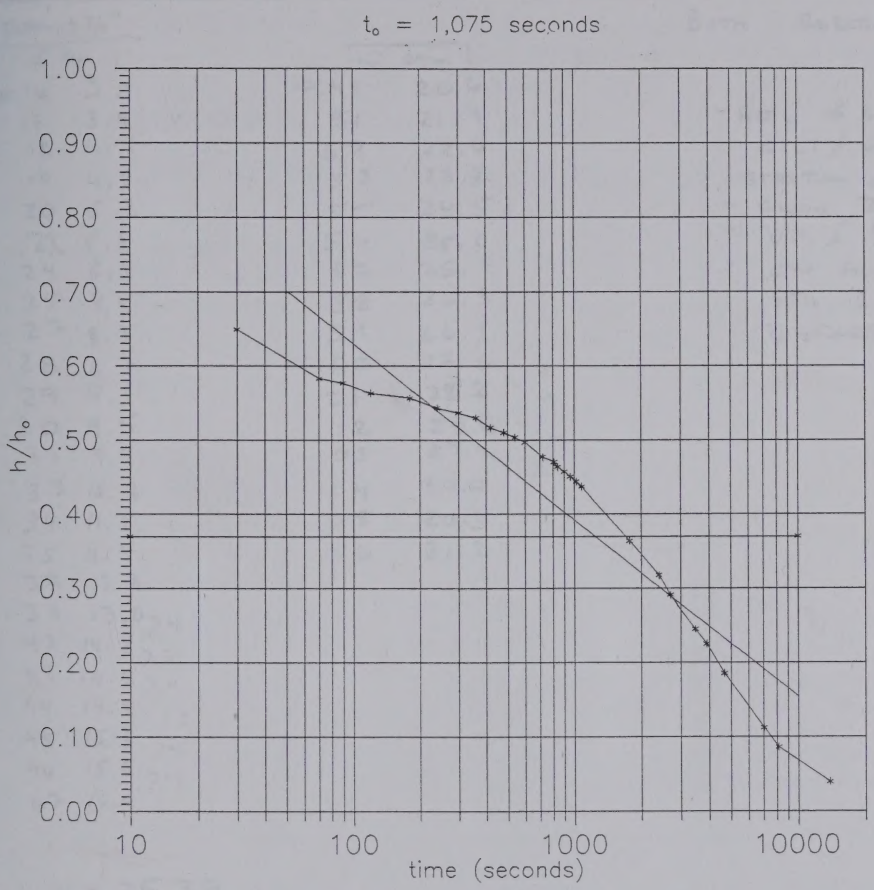
Time versus recovery plot of slug test in monitoring well MW-3, Unified Unified Disposal District landfill, Havre, Montana.



Time versus recovery plot of slug test in monitoring well MW-4 at the Unified Disposal landfill, Havre, Montana.



Time versus recovery plot of slug test in monitoring well MW-5 at the Unified Disposal landfill, Havre, Montana.



Time versus recovery plot of slug test in monitoring well MW-6 at the Unified Disposal landfill, Havre, Montana.

D&A

DAMSCHEN & ASSOCIATES, INC.

CONSULTING ENGINEERS

PROJECT UNIFIED

PROJ. NO. 93-00 PAGE 1 /

DATE 4/20/93 BY: BS GP-1

PERMEAMETER TEST

HOLE DEPTH 10 3/4"

BOTH RESERVOIRS

5 cm		10 cm	
10:16	3.0	10:49	20.6
17	3.9	51	21.9
18	4.4	52	22.6
19	4.8	53	23.2
20	5.3	55	24.5
22	5.8	56	25.0
24	6.9	57	25.7
25	7.5	58	26.3
27	8.3	59	26.9
28	8.7	11:00	27.6
29	9.1	01	28.2
30	9.5	02	28.8
31	9.9	03	29.4
33	10.7	04	30.0
34	11.1	05	30.6
35	11.4	06	31.2
37	12.2		
39	13.0		
42	14.2		
43	14.5		
44	14.9		
45	15.2		
46	15.6		
47	16.0		

- SOIL IS SANDY, CLAYEY SILT // UNDERLYING STRATUM MAY BE MORE CLAY RICH - PICKED UP A BIT OF CLAY ON AUGER TIPS // SOIL IS SOMEWHAT DISTURBED

$X = 35.39$

$\bar{R}_1 = 2.75$ cm/min $= 0.04583$ cm/sec

$\bar{R}_2 = 6$ cm/min $= 0.1$ cm/sec

$K_{fs} = 5.75 \times 10^{-3}$

K_{fs} and ϕ_m. When the Inner Reservoir only has been selected, use equations 3 and 4 on page 14 to calculate K_{fs} and ϕ_m. It is essential to use the correct equations to make the calculations because each equation incorporates a cell constant which corresponds to the cross-sectional area of the reservoir selected.

STANDARDIZED CALCULATIONS

HYDRAULIC CONDUCTIVITY AND MATRIC FLUX POTENTIAL

The following formulas are used to determine hydraulic conductivity K_{fs} and matric flux potential ϕ_m when following the standardized procedure in this manual.

When using both reservoirs:

Equation 1:

$$K_{fs} = (.0041)(X)(\overline{R}_2) - (.0054)(X)(\overline{R}_1)$$

Equation 2:

$$\phi_m = (.0572)(X)(\overline{R}_1) - (.0237)(X)(\overline{R}_2)$$

When using the Inner Reservoir:

Equation 3:

$$K_{fs} = (.0041)(Y)(\overline{R}_2) - (.0054)(Y)\cancel{(\overline{R}_2)}\ (\overline{R}_1)$$

Equation 4:

$$\phi_m = (.0572)(Y)(\overline{R}_1) - (.0237)(X)(\overline{R}_2)$$

X = Reservoir constant used when the reservoir combination is selected.

Y = Reservoir constant used when the inner reservoir only is selected.

NOTE:
The reservoir constants are stamped on the notched Reservoir Valve of the permeameter.

SORPTIVITY

When the volumetric water content of the soil can be measured or estimated with reasonable accuracy, soil sorptivity S can be calculated as follows:

$$S = \sqrt{2(\Delta\Theta)\phi_m}$$

Where $\Delta\Theta = \Theta_{fs} - \Theta_i$

Θ_i = initial volumetric water content
Θ_{fs} = field-saturated volumetric water content

ALPHA CONSTANT AND THE CONDUCTIVITY - PRESSURE HEAD RELATIONSHIP

Alpha is a constant which is dependent on the porous properties of soil. It is calculated as follows:

$$\alpha = K_{fs}/\phi_m$$

The Hydraulic Conductivity/Pressure-Head relationship, $K(\varphi)$ describes the change in K with soil suction. Generally, as soil suction increases, hydraulic conductivity decreases exponentially. For any soil suction (as measured in cm of water), the hydraulic conductivity can be predicted by the following equation.

$$K = K_{fs}[e^{(\alpha)(\varphi)}]$$

Where,

φ = soil water suction in cm of water
e = 2.71828 (base of natural logarithm)

NEGATIVE RESULTS

The results of measurements with the Guelph Permeameter can indicate soil heterogeneity. When a negative K_{fs} or ϕ_m value is calculated, it is indicative of the presence of a hydrologic discontinuity, typically caused by soil stratification or the presence of rodent and/or root holes. This underlines the value of a profile description. When a negative value for K_{fs} or ϕ_m is obtained, it indicates that further measurements are needed to account for the degree and kind of soil heterogeneity.

APPENDIX E. ANALYTICAL REPORTS OF GROUND WATER SAMPLES

ENERGY LABORATORIES

ENERGY LABORATORIES, INC.
P.O. BOX 30916 • 1107 SOUTH BROADWAY • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325
FAX (406) 252-6069 • 1-800-735-4489

LABORATORY REPORT

TO: Bruce Siegmund
ADDRESS: Damschen & Associates
P.O. Box 4817
Helena, MT 59604

LAB NO.: 93-14290-92
DATE: 04/28/93 ag

WATER ANALYSIS

Proj. No. 93-06, ~~UniField~~ UNIFIED BS Disposal Dist.
Sampled 04/20/93
Submitted 04/22/93
Analyzed 04/26/93

Lab No.	Identification	Total Suspended Solids, mg/l (ppm)
93-14290	MW-3	280
93-14291	MW-4	4
93-14292	MW-6	33

QUALITY ASSURANCE - DUPLICATE ANALYSIS

93-14290	Duplicate Analysis	281

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LABORATORY REPORT

TO: Bruce Siegmund
ADDRESS: Damschen & Associates
P.O. Box 4817
Helena, MT 59604

LAB NO.: 93-14293
DATE: 04/28/93 ag

WATER ANALYSIS

Proj. No. 93-06, ~~UniField~~ UNIFIED (BS) Disposal Dist., MW-5
Sampled 04/20/93
Submitted 04/22/93

Constituent	mg/l (ppm)	Date Analyzed
Total Suspended Solids	37	04/26/93
Total Dissolved Solids @ 180°C	15000	04/23/93
Chemical Oxygen Demand	15	04/23/93

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FAX (406) 252-6069 • 1-800-735-4489

LABORATORY REPORT

TO: Bruce Siegmund
ADDRESS: Damschen & Associates
P.O. Box 4817
Helena, MT 59604

LAB NO.: 93-14293
DATE: 04/28/93 ag

WATER ANALYSIS

Proj. No. 93-06, ~~UniField~~ UNIFIED (BS) Disposal Dist., MW-5
Sampled 04/20/93
Submitted 04/22/93

Constituent	mg/l (ppm)	Date Analyzed
Total Suspended Solids	37	04/26/93
Total Dissolved Solids @ 180°C	15000	04/23/93
Chemical Oxygen Demand	15	04/23/93

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AUG 18 1993
DAMSCHEN & ASSOCIATES

LABORATORY REPORT

TO: Damschen & Associates, Inc.
ADDRESS: P.O. Box 4817
Helena, MT 59604

LAB NO.: 93-32112
DATE: 08/11/93 crp
REVISED: 08/17/93 crp

WATER ANALYSIS

UniFied L.F. (Havre), M-2
Sampled 07/25/93 @ 0725
Submitted 07/28/93

Constituent	mg/l (ppm)	Date Analyzed
Potassium	9	07/29/93
Sodium	1350	07/29/93
Calcium	33	07/29/93
Magnesium	6	07/29/93
Sulfate	19	07/29/93
Chloride	1930	07/29/93
Carbonate	0	07/29/93
Bicarbonate	332	07/29/93
Total Dissolved Solids @ 180°C	3970	07/29/93
Total Alkalinity as $CaCO_3$	272	07/29/93
Specific Conductance @ 25°C	6850 μmhos/cm	07/29/93
pH	7.9 s.u.	07/29/93
Nitrate as N	<0.05	07/29/93
Ammonia as N	2.9	07/29/93
Chemical Oxygen Demand	73	07/29/93
Total Suspended Solids	194	07/29/93
Total Cyanide	<0.005	07/28/93
Dissolved Metals		
Arsenic	<0.005	08/04/93
Barium	0.6	07/31/93
Cadmium	<0.001	07/31/93
Chromium	<0.01	07/31/93
Iron	0.04	07/31/93
Lead	<0.01	08/04/93
Manganese	0.05	07/31/93
Mercury	<0.001	07/29/93
Selenium	<0.005	07/30/93
Silver	<0.005	07/31/93

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FAX (406) 252-6069 • 1-800-735-4489

LABORATORY REPORT

TO:	Damschen & Associates, Inc.	LAB NO.:	93-32113
ADDRESS:	P.O. Box 4817	DATE:	08/11/93 crp
	Helena, MT 59604	REVISED:	08/17/93 crp

WATER ANALYSIS

UniFied L.F. (Havre), M-3
Sampled 07/25/93 @ 1240
Submitted 07/28/93

Constituent	mg/l (ppm)	Date Analyzed
Potassium	7	08/03/93
Sodium	2260	08/03/93
Calcium	67	08/03/93
Magnesium	15	08/03/93
Sulfate	3710	08/07/93
Chloride	108	08/07/93
Carbonate	0	07/29/93
Bicarbonate	1600	07/29/93
Total Dissolved Solids @ 180°C	7100	07/29/93
Total Alkalinity as $CaCO_3$	1310	07/29/93
Specific Conductance @ 25°C	8680 μmhos/cm	07/29/93
pH	7.7 s.u.	07/29/93
Nitrate as N	<0.05	07/29/93
Ammonia as N	4.3	07/29/93
Chemical Oxygen Demand	52	07/29/93
Total Suspended Solids	335	07/29/93
Total Cyanide	<0.005	07/28/93
Dissolved Metals		
Arsenic	<0.005	08/04/93
Barium	<0.1	07/31/93
Cadmium	<0.001	07/31/93
Chromium	<0.01	07/31/93
Iron	0.04	07/31/93
Lead	0.02	07/31/93
Manganese	0.05	07/31/93
Mercury	<0.001	07/29/93
Selenium	<0.005	07/30/93
Silver	<0.005	07/31/93

ENERGY LABORATORIES, INC.

P.O. Box 3258 • 730 South Broadway • Billings, MT 59103-3258 • (406) 252-6325
Fax (406) 252-6069 • 1-800-735-4489

LABORATORY REPORT

TO: Demaree & Associates, Inc.
ADDRESS: P.O. Box 4847
Helena, MT 59604

LAB NO.: 93-3247-2
DATE: 08/11/93 wp
REVISED: 08/17/93 wp

WATER ANALYSIS

Unified L-7 (Haven) M-3
Sampled 07/28/93 @ 1240
Submitted 07/28/93

Constituent	Test Result	Date Analyzed
Potassium	7	08/09/93
Sodium	2260	08/09/93
Calcium	87	08/09/93
Magnesium	16	08/09/93
Sulfate	3710	08/09/93
Chloride	108	08/09/93
Carbonate	0	07/29/93
Bicarbonate	1500	07/29/93
Total Dissolved Solids @ 180°C	7100	07/29/93
Total Alkalinity as $CaCO_3$	1310	07/29/93
Specific Conductance @ 25°C	8880 micromhos	07/29/93
pH	7.7 s.u.	07/29/93
Nitrate as N	<0.05	07/29/93
Ammonia as N	<.5	07/29/93
Chemical Oxygen Demand	52	07/29/93
Total Suspended Solids	235	07/29/93
Total Cyanide	<0.005	07/29/93

Dissolved Metals		
Arsenic	<0.005	08/04/93
Barium	<0.1	07/31/93
Cadmium	<0.001	07/31/93
Chromium	<0.01	07/31/93
Iron	0.04	07/31/93
Lead	0.02	07/31/93
Magnesium	0.05	07/31/93
Mercury	<0.001	07/29/93
Selenium	<0.005	07/30/93
Silver	<0.01	07/31/93

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FAX (406) 252-6069 • 1-800-735-4489

LABORATORY REPORT

TO: Damschen & Associates, Inc.
ADDRESS: P.O. Box 4817
Helena, MT 59604

LAB NO.: 93-32114
DATE: 08/11/93 crp
REVISED: 08/17/93 crp

WATER ANALYSIS

UniFied L.F. (Havre), M-4
Sampled 07/25/93 @ 1550
Submitted 07/28/93

Constituent	mg/l (ppm)		Date Analyzed
Potassium	5		08/03/93
Sodium	887		08/03/93
Calcium	11		08/03/93
Magnesium	3		08/03/93
Sulfate	521		08/07/93
Chloride	578		08/07/93
Carbonate	7		07/29/93
Bicarbonate	769		07/29/93
Total Dissolved Solids @ 180°C	2630		07/29/93
Total Alkalinity as $CaCO_3$	641		07/29/93
Specific Conductance @ 25°C	3880	µmhos/cm	07/29/93
pH	8.4	s.u.	07/29/93
Nitrate as N	10.1		07/29/93
Ammonia as N	1.7		07/29/93
Chemical Oxygen Demand	111		07/29/93
Total Suspended Solids	660		07/29/93
Total Cyanide	<0.005		07/28/93
Dissolved Metals			
Arsenic	0.008		08/04/93
Barium	0.1		07/31/93
Cadmium	<0.001		07/31/93
Chromium	<0.01		07/31/93
Iron	0.23		07/31/93
Lead	0.05		07/31/93
Manganese	0.04		07/31/93
Mercury	<0.001		07/29/93
Selenium	0.012		07/30/93
Silver	<0.005		07/31/93

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ENERGY LABORATORIES INC.

P.O. BOX 3258 • 1120 SOUTH PACKARD • CASPER, WY 82602-3258
(307) 235-0515 • FAX (307) 234-1639

LABORATORY REPORT

TO: Dimension 3 Services, Inc.
ADDRESS: P.O. Box 1317
Moore, MT 59643

LAB NO.: [illegible]
DATE: [illegible]
REVISED: [illegible]

WATER ANALYSIS

Marsha L. Hayes, M.S.
Sampled 07/29/99 @ 1040
Submitted 07/29/99

Constituent	mg/L (ppm)	Date Analyzed
Calcium	8	[illegible]
Sodium	687	[illegible]
Potassium	17	[illegible]
Magnesium	3	[illegible]
Sulfate	831	[illegible]
Chloride	878	[illegible]
Carbonate	7	[illegible]
Bicarbonate	763	[illegible]
Total Dissolved Solids @ 180°C	2820	[illegible]
Total Alkalinity as $CaCO_3$	641	[illegible]
Specific Conductance @ 25°C	2830 umhos/cm	[illegible]
pH	8.4 s.u.	[illegible]
Nitrate as N	10.1	[illegible]
Ammonia as N	1.7	[illegible]
Chemical Oxygen Demand	111	[illegible]
Total Suspended Solids	160	[illegible]
Total Cyanide	<0.005	[illegible]

Dissolved Metals

Arsenic	0.005	[illegible]
Selenium	0.1	[illegible]
Cadmium	<0.001	[illegible]
Chromium	<0.01	[illegible]
Iron	0.23	[illegible]
Lead	0.05	[illegible]
Manganese	0.04	[illegible]
Mercury	<0.001	[illegible]
Selenium	0.019	[illegible]
Silver	<0.005	[illegible]

ENERGY LABORATORIES

ENERGY LABORATORIES, INC.
P.O. BOX 30916 • 1107 SOUTH BROADWAY • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325
FAX (406) 252-6069 • 1-800-735-4489

LABORATORY REPORT

TO: Damschen & Associates, Inc.
ADDRESS: P.O. Box 4817
Helena, MT 59604

LAB NO.: 93-32115
DATE: 08/11/93 crp
REVISED: 08/17/93 crp

WATER ANALYSIS

UniFied L.F. (Havre), M-5
Sampled 07/25/93 @ 2020
Submitted 07/28/93

Constituent	mg/l (ppm)		Date Analyzed
Potassium	19		08/03/93
Sodium	4420		08/03/93
Calcium	419		08/03/93
Magnesium	255		08/03/93
Sulfate	10500		08/07/93
Chloride	130		08/07/93
Carbonate	0		07/29/93
Bicarbonate	1040		07/29/93
Total Dissolved Solids @ 180°C	16500		07/29/93
Total Alkalinity as $CaCO_3$	852		07/29/93
Specific Conductance @ 25°C	16700	µmhos/cm	07/29/93
pH	7.4	s.u.	07/29/93
Nitrate as N	11.3		07/29/93
Ammonia as N	<0.1		07/29/93
Chemical Oxygen Demand	52		07/29/93
Total Suspended Solids	200		07/29/93
Total Cyanide	<0.005		07/28/93
Dissolved Metals			
Arsenic	<0.005		08/04/93
Barium	<0.1		07/31/93
Cadmium	<0.001		07/31/93
Chromium	<0.01		07/31/93
Iron	<0.03		07/31/93
Lead	<0.01		08/04/93
Manganese	1.88		07/31/93
Mercury	<0.001		07/29/93
Selenium	0.007		07/30/93
Silver	<0.005		07/31/93

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LABORATORY REPORT

TO: Damschen & Associates, Inc.
ADDRESS: P.O. Box 4817
Helena, MT 59604

LAB NO.: 93-32116
DATE: 08/11/93 crp
REVISED: 08/17/93 crp

WATER ANALYSIS

UniFied L.F. (Havre), M-6
Sampled 07/25/93 @ 1305
Submitted 07/28/93

Constituent	mg/l (ppm)	Date Analyzed
Potassium	9	08/03/93
Sodium	2510	08/03/93
Calcium	189	08/03/93
Magnesium	74	08/03/93
Sulfate	4790	08/07/93
Chloride	234	08/07/93
Carbonate	0	07/29/93
Bicarbonate	1390	07/29/93
Total Dissolved Solids @ 180°C	8770	07/29/93
Total Alkalinity as $CaCO_3$	1140	07/29/93
Specific Conductance @ 25°C	10300 μmhos/cm	07/29/93
pH	7.4 s.u.	07/29/93
Nitrate as N	1.98	07/29/93
Ammonia as N	4.0	07/29/93
Chemical Oxygen Demand	57	07/29/93
Total Suspended Solids	290	07/29/93
Total Cyanide	<0.005	07/28/93
Dissolved Metals		
Arsenic	0.018	08/04/93
Barium	<0.1	07/31/93
Cadmium	0.001	07/31/93
Chromium	<0.01	07/31/93
Iron	<0.03	07/31/93
Lead	0.02	07/31/93
Manganese	0.25	07/31/93
Mercury	<0.001	07/29/93
Selenium	<0.005	07/30/93
Silver	<0.005	07/31/93

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LABORATORY REPORT

TO: Damschen & Associates, Inc.
ADDRESS: P.O. Box 4817
Helena, MT 59604

LAB NO.: 93-32112
DATE: 08/11/93 crp
REVISED: 08/17/93 crp

WATER ANALYSIS

UniFied L.F. (Havre), M-2
Sampled 07/25/93 @ 1240
Submitted 07/28/93
Analyzed 07/29/93

Constituent	µg/l	Constituent	µg/l
Benzene	<1.0	1,1-Dichloroethane	<1.0
Bromochloromethane	<1.0	1,2-Dichloroethane	<1.0
Bromodichloromethane	<1.0	Iodomethane	<1.0
cis-1,3-Dichloropropene	<1.0	Methylene chloride	<1.0
trans-1,3-Dichloropropene	<1.0	1,1-Dichloroethene	<1.0
1,4-Difluorobenzene	<1.0	trans-1,2-Dichloroethene	<1.0
Ethylbenzene	<1.0	Styrene	<1.0
Ethyl methacrylate	<1.0	1,1,2,2-Tetrachloroethane	<1.0
4-Bromofluorobenzene	<10	Toluene	<1.0
Bromoform	<1.0	1,1,1-Trichloroethane	<1.0
Bromomethane	<1.0	1,1,2-Trichloroethane	<1.0
Carbon tetrachloride	<1.0	Trichloroethene	<1.0
Chlorobenzene	<1.0	Trichlorofluoromethane	<1.0
Dibromochloromethane	<1.0	1,2,3-Trichloropropane	<1.0
Chloroethane	<1.0	Vinyl acetate	<1.0
2-Chloroethyl vinyl ether	<1.0	Vinyl chloride	<1.0
Chloroform	<1.0	Xylenes	<1.0
Chloromethane	<1.0	Tetrachloroethene	<1.0
Dibromomethane	<1.0		
Dichlorodifluoromethane	<1.0		

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LABORATORY REPORT

TO: Damschen & Associates, Inc.
ADDRESS: P.O. Box 4817
Helena, MT 59604

LAB NO.: 93-32113
DATE: 08/11/93 crp
REVISED: 08/17/93 crp

WATER ANALYSIS

UniFied L.F. (Havre), M-3
Sampled 07/25/93 @ 1240
Submitted 07/28/93
Analyzed 07/29/93

Constituent	µg/l	Constituent	µg/l
Benzene	<1.0	1,1-Dichloroethane	<1.0
Bromochloromethane	<1.0	1,2-Dichloroethane	<1.0
Bromodichloromethane	<1.0	Iodomethane	<1.0
cis-1,3-Dichloropropene	<1.0	Methylene chloride	<1.0
trans-1,3-Dichloropropene	<1.0	1,1-Dichloroethene	<1.0
1,4-Difluorobenzene	<1.0	trans-1,2-Dichloroethene	<1.0
Ethylbenzene	<1.0	Styrene	<1.0
Ethyl methacrylate	<1.0	1,1,2,2-Tetrachloroethane	<1.0
4-Bromofluorobenzene	<10	Toluene	<1.0
Bromoform	<1.0	1,1,1-Trichloroethane	<1.0
Bromomethane	<1.0	1,1,2-Trichloroethane	<1.0
Carbon tetrachloride	<1.0	Trichloroethene	<1.0
Chlorobenzene	<1.0	Trichlorofluoromethane	<1.0
Dibromochloromethane	<1.0	1,2,3-Trichloropropane	<1.0
Chloroethane	<1.0	Vinyl acetate	<1.0
2-Chloroethyl vinyl ether	<1.0	Vinyl chloride	<1.0
Chloroform	<1.0	Xylenes	<1.0
Chloromethane	<1.0	Tetrachloroethene	<1.0
Dibromomethane	<1.0		
Dichlorodifluoromethane	<1.0		

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LABORATORY REPORT

TO: Damschen & Associates, Inc.
ADDRESS: P.O. Box 4817
Helena, MT 59604

LAB NO.: 93-32114
DATE: 08/11/93 crp
REVISED: 08/17/93 crp

WATER ANALYSIS

UniFied L.F. (Havre), M-4
Sampled 07/25/93 @ 1550
Submitted 07/28/93
Analyzed 07/30/93

Constituent	µg/l	Constituent	µg/l
Benzene	<1.0	1,1-Dichloroethane	<1.0
Bromochloromethane	<1.0	1,2-Dichloroethane	<1.0
Bromodichloromethane	<1.0	Iodomethane	<1.0
cis-1,3-Dichloropropene	<1.0	Methylene chloride	<1.0
trans-1,3-Dichloropropene	<1.0	1,1-Dichloroethene	<1.0
1,4-Difluorobenzene	<1.0	trans-1,2-Dichloroethene	<1.0
Ethylbenzene	<1.0	Styrene	<1.0
Ethyl methacrylate	<1.0	1,1,2,2-Tetrachloroethane	<1.0
4-Bromofluorobenzene	<10	Toluene	<1.0
Bromoform	<1.0	1,1,1-Trichloroethane	<1.0
Bromomethane	<1.0	1,1,2-Trichloroethane	<1.0
Carbon tetrachloride	<1.0	Trichloroethene	<1.0
Chlorobenzene	<1.0	Trichlorofluoromethane	<1.0
Dibromochloromethane	<1.0	1,2,3-Trichloropropane	<1.0
Chloroethane	<1.0	Vinyl acetate	<1.0
2-Chloroethyl vinyl ether	<1.0	Vinyl chloride	<1.0
Chloroform	<1.0	Xylenes	<1.0
Chloromethane	<1.0	Tetrachloroethene	<1.0
Dibromomethane	<1.0		
Dichlorodifluoromethane	<1.0		

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LABORATORY REPORT

TO: Damschen & Associates, Inc.
ADDRESS: P.O. Box 4817
Helena, MT 59604

LAB NO.: 93-32115
DATE: 08/11/93 crp
REVISED: 08/17/93 crp

WATER ANALYSIS

UniFied L.F. (Havre), M-5
Sampled 07/25/93 @ 2020
Submitted 07/28/93
Analyzed 07/29/93

Constituent	µg/l	Constituent	µg/l
Benzene	<1.0	1,1-Dichloroethane	<1.0
Bromochloromethane	<1.0	1,2-Dichloroethane	<1.0
Bromodichloromethane	<1.0	Iodomethane	<1.0
cis-1,3-Dichloropropene	<1.0	Methylene chloride	<1.0
trans-1,3-Dichloropropene	<1.0	1,1-Dichloroethene	<1.0
1,4-Difluorobenzene	<1.0	trans-1,2-Dichloroethene	<1.0
Ethylbenzene	<1.0	Styrene	<1.0
Ethyl methacrylate	<1.0	1,1,2,2-Tetrachloroethane	<1.0
4-Bromofluorobenzene	<10	Toluene	<1.0
Bromoform	<1.0	1,1,1-Trichloroethane	<1.0
Bromomethane	<1.0	1,1,2-Trichloroethane	<1.0
Carbon tetrachloride	<1.0	Trichloroethene	<1.0
Chlorobenzene	<1.0	Trichlorofluoromethane	<1.0
Dibromochloromethane	<1.0	1,2,3-Trichloropropane	<1.0
Chloroethane	<1.0	Vinyl acetate	<1.0
2-Chloroethyl vinyl ether	<1.0	Vinyl chloride	<1.0
Chloroform	<1.0	Xylenes	<1.0
Chloromethane	<1.0	Tetrachloroethene	<1.0
Dibromomethane	<1.0		
Dichlorodifluoromethane	<1.0		

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LABORATORY REPORT

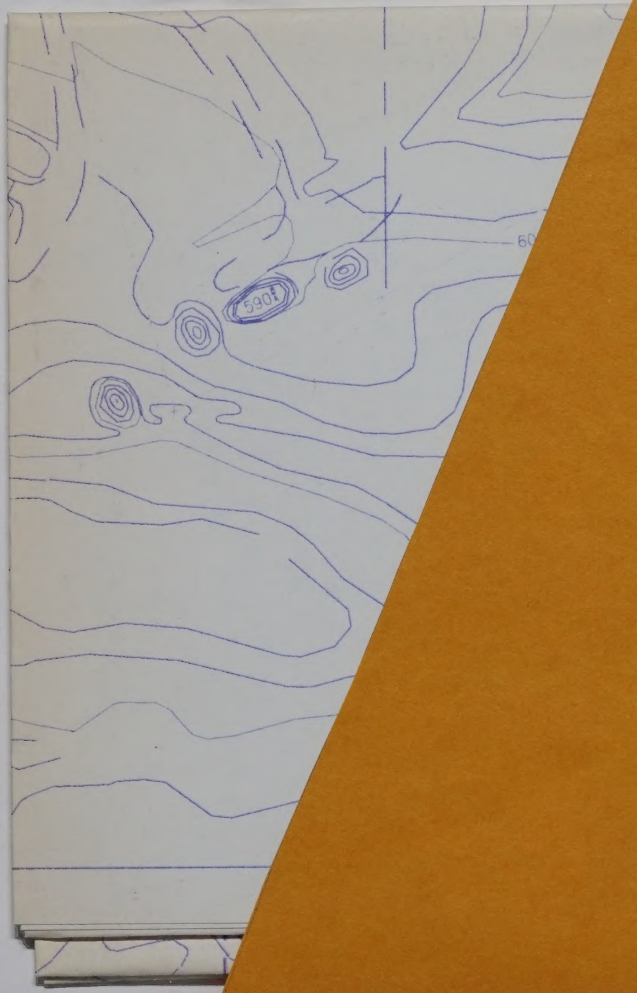
TO: Damschen & Associates, Inc.
ADDRESS: P.O. Box 4817
Helena, MT 59604

LAB NO.: 93-32116
DATE: 08/11/93 crp
REVISED: 08/17/93 crp

WATER ANALYSIS

UniFied L.F. (Havre), M-6
Sampled 07/25/93 @ 1305
Submitted 07/28/93
Analyzed 07/30/93

Constituent	µg/l	Constituent	µg/l
Benzene	<1.0	1,1-Dichloroethane	<1.0
Bromochloromethane	<1.0	1,2-Dichloroethane	<1.0
Bromodichloromethane	<1.0	Iodomethane	<1.0
cis-1,3-Dichloropropene	<1.0	Methylene chloride	<1.0
trans-1,3-Dichloropropene	<1.0	1,1-Dichloroethene	<1.0
1,4-Difluorobenzene	<1.0	trans-1,2-Dichloroethene	<1.0
Ethylbenzene	<1.0	Styrene	<1.0
Ethyl methacrylate	<1.0	1,1,2,2-Tetrachloroethane	<1.0
4-Bromofluorobenzene	<10	Toluene	<1.0
Bromoform	<1.0	1,1,1-Trichloroethane	<1.0
Bromomethane	<1.0	1,1,2-Trichloroethane	<1.0
Carbon tetrachloride	<1.0	Trichloroethene	<1.0
Chlorobenzene	<1.0	Trichlorofluoromethane	<1.0
Dibromochloromethane	<1.0	1,2,3-Trichloropropane	<1.0
Chloroethane	<1.0	Vinyl acetate	<1.0
2-Chloroethyl vinyl ether	<1.0	Vinyl chloride	<1.0
Chloroform	<1.0	Xylenes	<1.0
Chloromethane	<1.0	Tetrachloroethene	<1.0
Dibromomethane	<1.0		
Dichlorodifluoromethane	<1.0		


590ft
60


SHOP WELL
APPROXIMATE LIMIT OF PROPOSED EXPANSION
TP-E9
P-3
UDD-16
TP-25
TP-E10
TP-24
TP-E12
UDD-17
TP-E13
TP-E11
TP-E14
TP-E15
TB-3
TP-23
TP-22
UDD-12
APPROXIMATE WASTE AREA THROUGH 1989
UDD-11
OBSERVATION WELL
MW-5 (UDD-19)
B
C
TP-30
TP-27
TP-28
TP-29
TP-11
TP-9
TB-1
TP-7
TP-33
TP-8
TP-10
TP-13
TP-14
TP-1
TP-2
TP-31
TP-15
MW-2

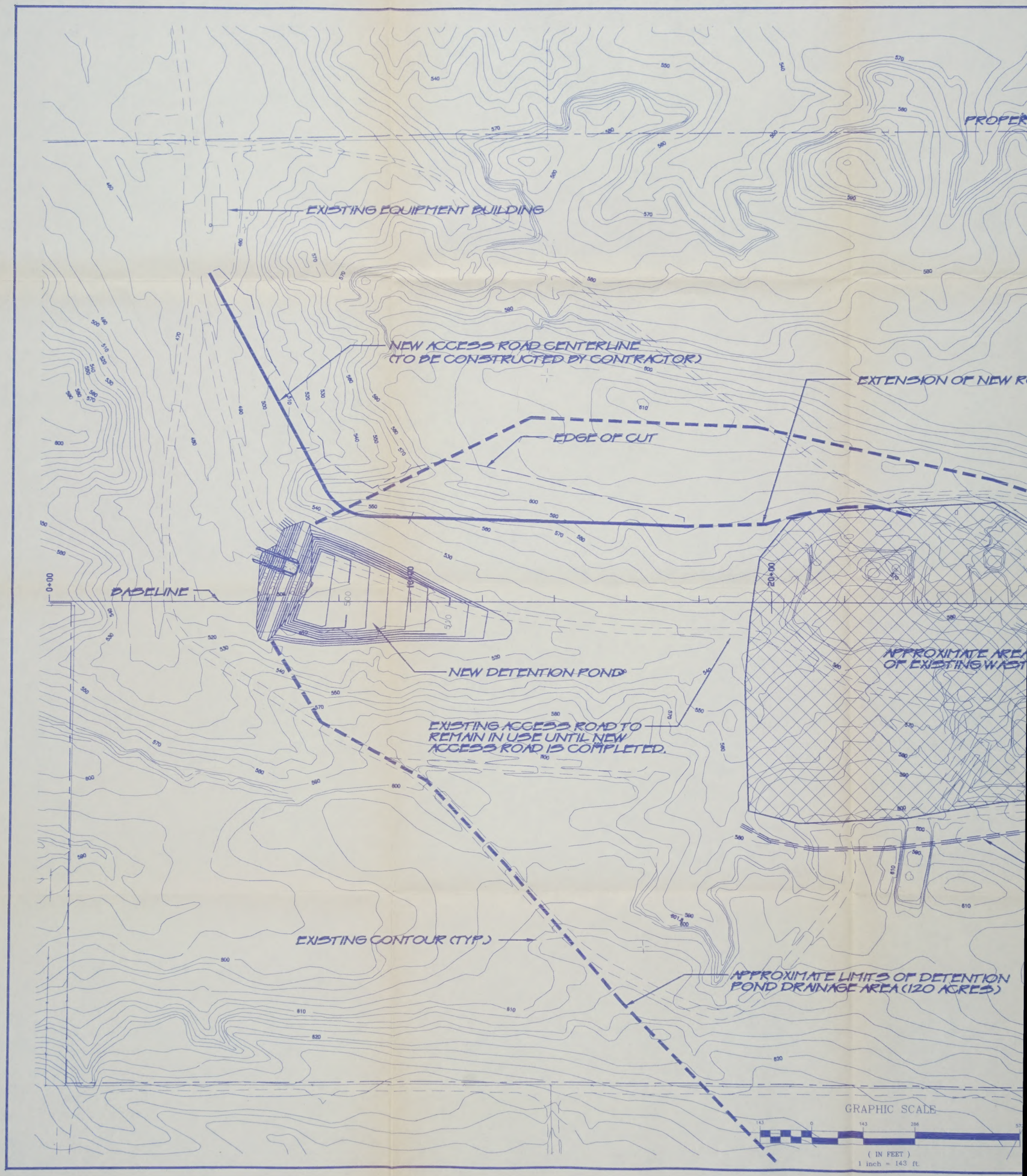
Damschen & Associates, Inc.
CONSULTING ENGINEERS
• 2030 11th Ave., Suite 11 •
• HELENA, MONTANA •

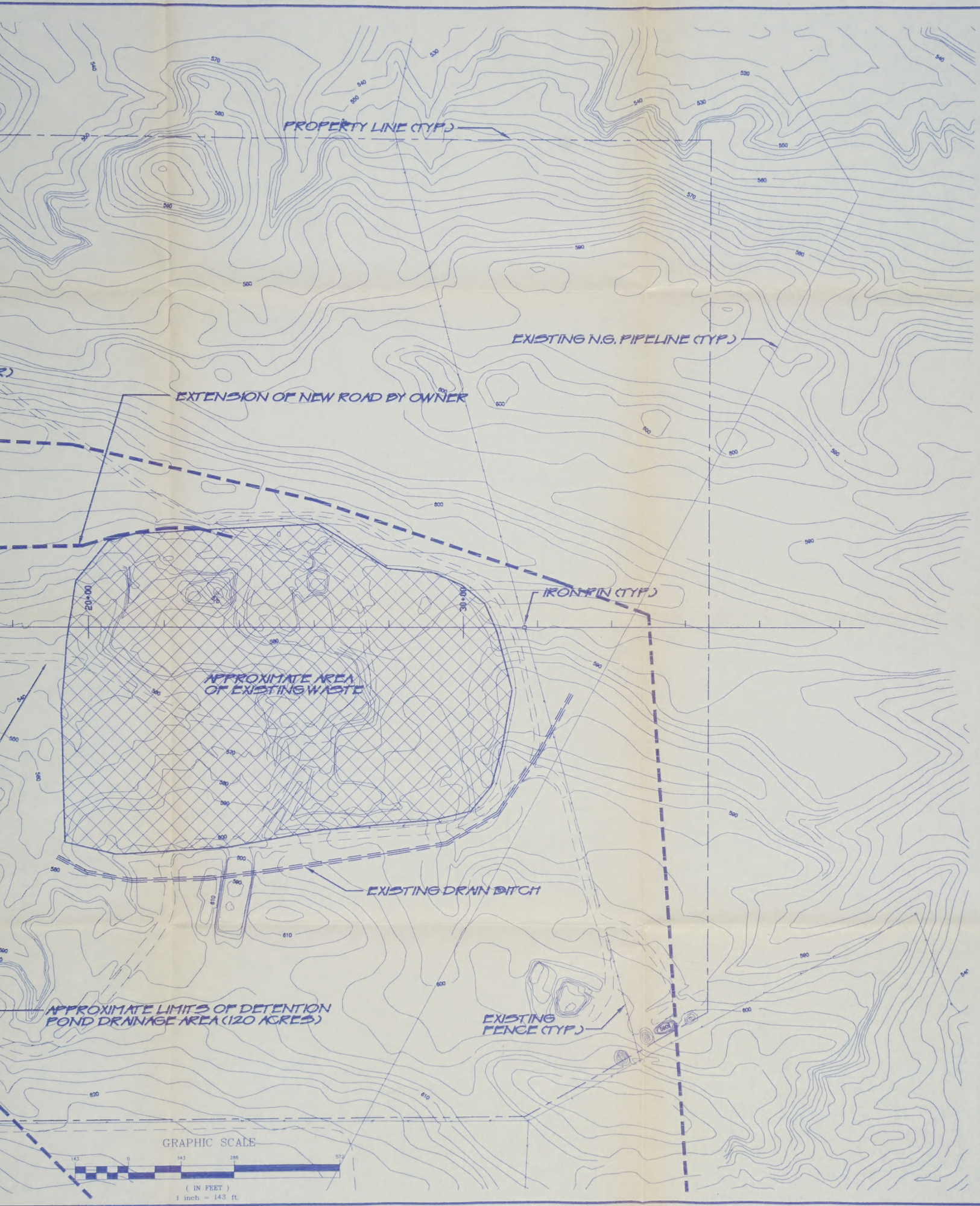
JOB / ACAD NUMBER	9158.1SAO
DRAWN BY	W. SMITH
APPROVED BY	D. McCAULEY
CHECKED BY	J. McGOWAN
DATE	FEBRUARY, 1993

PROJECT TITLE

Revised site map of the Unified Disposal District landfill Havre, Montana.

PLATE 1


PROPER
EXISTING EQUIPMENT BUILDING
NEW ACCESS ROAD CENTERLINE
(TO BE CONSTRUCTED BY CONTRACTOR)
EXTENSION OF NEW R
EDGE OF CUT
0+00
BASELINE
10+00
20+00
NEW DETENTION POND
APPROXIMATE AREA
OF EXISTING WAST
EXISTING ACCESS ROAD TO
REMAIN IN USE UNTIL NEW
ACCESS ROAD IS COMPLETED.
EXISTING CONTOUR (TYP.)
APPROXIMATE LIMITS OF DETENTION
POND DRAINAGE AREA (120 ACRES)
GRAPHIC SCALE
(IN FEET)
1 inch = 143 ft.



MONTANA
BARRY E. DAMSCHEN
3837E
REGISTERED PROFESSIONAL ENGINEER

Damschen & Associates, Inc.
CONSULTING ENGINEERS
• 2030 11th Ave., Suite 11 •
• HELENA, MONTANA

JOB/ACAD NUMBER	PLOT INFO
9306	
DRAWN BY	
J. PILCHER	
APPROVED BY	
B. DAMSCHEN	
CHECKED BY	
B. DAMSCHEN	
DATE	
SEPT., 1993	

PROJECT TITLE
UNIFIED DISPOSAL DISTRICT

SHEET TITLE
SITE PLAN

#	DATE	REVISION
△		
△		
△		
△		
△		
△		

SHEET NO.

GROUP III DISPOSAL AREA

28K-90W
9 X 12